TAA 173/65/04
14 April 1953

~~CONFIDENTIAL~~

YUGOSLAVIA

ENERGY RESOURCES OF YUGOSLAVIA

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CONTENTS

Introduction

This is a provisional report on a six-month energy resources mission in Yugoslavia.

The mission originated, so far as the writer is aware, in the visit to Yugoslavia by Director Keenleyside in mid-1951. The scope of the mission as outlined shortly thereafter was as follows:

"(1) To make a survey of energy resources in Yugoslavia;

(2) To advise the Government of Yugoslavia on:

- (a) the possibilities of exploitation on a regional or national basis with respect to each form of energy;
- (b) the priority in which the various forms of energy should be developed;
- (c) the economic implications of such development;
- (d) methods of development;
- (e) methods of utilization and distribution of energy produced with special reference to export possibilities;

(3) To discuss steps already taken by the Yugoslav Government to develop power resources and to advise the Government on the possible nature and extent of any further assistance the United Nations could provide in this field."

Because this was obviously more than one expert could accomplish within the 90-day term of the original assignment, and was in fact of a scope and complexity that called for a team approach, TAA authorized the greatest flexibility in implementing the assignment. Accordingly the first task was to re-define the mission in terms which were in accordance with the desire of the Government and which at the same time were within the limits of accomplishment.

The preparatory nature of the mission was generally recognized. In its initial conference Government officials stated that they knew that Yugoslavia was rich in energy resources but that they needed a competent statement, in terms that are consistent with international usage, as to the character and extent of these resources. The Government asked that we consider all energy resources, methods of exploitation and national energy requirements. Principal interest was clearly in hydro, however, and in possible hydro exports to central Europe.

This was an ambitious program for the limited time that was available. In an effort to accomplish as much as possible, Government officials accepted the responsibility for assembling and organizing data with respect to

known energy resources and with regard to needs for further investigation and exploration. Arrangements for a joint and coordinated approach to the problem having been made, the Government then proposed that the writer proceed to the Capitals of the several Republics which under the present decentralized operation of the Government are centers of exploration and exploitation. Officials of the Republics and the various institutes and enterprises participated fully in the review of present knowledge on energy resources and consideration of a program of further exploration.

Because of the continuous absence in Geneva of Mr. Stejepan Han, director of the Institute to which I was assigned, and because of the Government's desire that I be present in Geneva during an ECE conference on energy exports, I returned to that city in late November for a week of conferences with Mr. Han and ECE staff members. In this discussion the Government's concept of the mission became more clearly defined. Its interest was stated to be primarily in obtaining a thoroughly competent inventory of its energy resources, with only such incidental reference to development and utilization as time permitted. Most specifically it was agreed that:

(1) The mission is exploratory in nature, its primary function being to lay the groundwork for a comprehensive series of studies to be undertaken over the next several years.

(2) The Government's primary interest is to complete its inventory of energy resources as quickly, economically, and effectively as possible.

(3) The Government desires that technical assistance be provided at this time with regard to:

- (a) the method for completing the inventory in the most acceptable manner;
- (b) advice as to the instruments, equipment and organization of the work; and
- (c) actual provision of instruments, literature, fellowships and foreign experts.

With this more manageable approach, the Government requested that the mission be extended for a second three months. Mr. Han also asked that a preliminary report be available for discussion in February at a conference in Belgrade on Yugoslav energy resources. This conference was to be preparatory in nature for an ECE-sponsored meeting in Geneve in mid-February on hydropower exports.

Accordingly the writer returned to Belgrade to concentrate on the problems involved in completion of an energy resources inventory. The essentials of the approach to be taken could be stated in the following simplified terms:

- (a) what data are now available, i.e. what is the present state of knowledge with respect to energy resources;

(b) what further data are needed to complete the inventory in acceptable terms;
(c) what program is required to complete the data including work by Yugoslav officials, engineers and scientists and foreign assistance.

December and January were utilized to bring together the material which had been prepared by various officials and engineers in accordance to the previous arrangements. As is always the case in such group efforts, the data was of uneven quality, although much was of the highest quality and adequacy. It became clear, however, that mechanical problems involved in the assembly and translation of materials prepared by others, and the actual preparation of an integrated report on Yugoslav energy resources were such that within the time limits available, it was not practicable to attempt any systematic compilation of data. This mission must rather confine itself to methods and plans by which others might undertake the work most effectively.

The three-day Energy Resources Conference held in Belgrade in February was attended by leading engineers and scientists from all Republics. It was apparently succesful in directing thinking to problems of completing and improving the energy resources inventory. The attached summary report (see Appendix 1) indicates the action taken to organize working groups of Yugoslav scientists and engineers for the purpose. The use of working committees in a carefully prepared and coordinated program was proposed by the writer as the most likely device to utilize the talents available and to achieve early and effective results. The success of this effort will depend entirely on the extent to which continued direction and guidance can be provided.

During January and February also, attention was given to the problem of energy exports to central Europe in the preparation of the Yugoslav delegation to the forthcoming meeting on energy exports to be held in Geneva. Both before and after the Geneva conference the writer advised in such ways as he could with respect to the analyses of potential hydro resources available for export and the engineering organization which should be set up to direct the necessary studies. Thus the mission may have had some of the practical value envisaged by Mr. Keenleyside.

The energy resources to which it has been possible to direct attention during this short mission, includes only hydro-power and fossil fuels (oil and gas, solid fuels and oil shales). It has not been possible to include either fuelwood or the minor energy resources. Fuelwood at present accounts for almost half the energy consumption of Yugoslavia. It has recently, however, been the subject of a comprehensive study and report by the Government. As to the minor energy resources, only wind energy seemed to be of particular promise in Yugoslavia, and it could best be handled by a special study. Neither tidal power, solar energy, geothermal sources, or submarine temperature differentials appeared to offer immediate or substantial prospects of exploitation although attention to them should not be continuously deferred.

This report will present a summary of the data now available on the hydro and fossil fuel resources, point out the gaps in these data, and suggest so far as possible the most likely steps to improve or complete the inventory.

Because of the limitations of the writer's experience the fossil fuels are presented more tentatively than hydro, but with the aim of providing others who are more competent in fossil fuels with more perspective to enable them to undertake any further work which may be desired, with a minimum of waste motion.

Amplifying materials are presented in the form of appendixes, several of which are believed to contain materials which have not hitherto been available. Others are included either for convenience of reference, or to indicate the current thinking of Yugoslav engineers.

It is impossible to make adequate acknowledgement to all the individual and the organizations who have participated in the work of the mission and contributed to this report. The Yugoslav Government has at all times made its records and its facilities fully available. Acknowledgement must be particularly made to Messrs. Dular and Han of the Institute of Planning of the National Government under whose sponsorship and auspices the mission was formulated and conducted, and the Foreign Office for its interest and cooperation. Acknowledgement must also be made to the many officials, engineers and scientists from the Governments of the six Republics, the technical and scientific institutes, and the various enterprises for the study and exploitation of energy resources.

The Technical Assistance Administration in New York and Geneva has been most understanding and helpful throughout the course of the work. The TAB Liaison Office in Belgrade has been invaluable in making its facilities and counsel available.

Individual recognition must be given, however, to Dr. Ing. Vladimir Slebinger of the staff of the Institute for Technical and Economic Research who was assigned to the mission for its entire duration, and whose extensive knowledge of Yugoslavia and professional competence were invaluable.

I. HYDROPOWER

A. Summary Perspectives

1. Physical base for Yugoslav hydropower

The waters of Yugoslavia's rugged terrain constitute perhaps its most valuable energy resource - large in magnitude and non-depletable.

This power potential derives from the happy combination of high mountains and heavy rainfall. The Julian Alps with their related structures rise to heights of 2800 meters. The Dinaric Alps extend down the entire length of the Adriatic coast at heights of 1500 to 2500 meters. From the ridges, the land drops quickly toward the Adriatic or the plains of the Sava and the Danube, thus creating the steep gradients which, together with the large streamflow, establish conditions favourable for hydropower.

Warm moisture-laden winds from the Mediterranean sweep northward over these Alpine mountains during much of the year, rising and cooling as they pass, their moisture condensing in the form of rain or snow. The highest rainfall in Europe is to be found in the mountains of Montenegro (more than 6000 cm per year). Having lost most of their moisture in the mountains the winds are comparatively dry as they reach the interior plains. The lowest rainfall in Yugoslavia (500 cm per year) is thus found in Macedonia only 125 kilometers from the point of the highest rainfall on the Continent.

The climate of the northern plains and much of the interior of Yugoslavia is continental and is characterised by smaller but more uniform rainfall through the year, with frequent summer storms. This inland climate extends south to but does not include the upper slopes of the Dinaric range. The occasional summer showers are not sufficient to prevent summer droughts.

The significant feature of the heavy precipitation on the mountainous area is that it occurs for the most part in the winter months. This is the so-called "Mediterranean pattern", a pattern which prevails in the Appenine peninsula, in the southern Balkan Peninsula including the Adriatic coast of Yugoslavia, on the southeast slopes of the Alps, and in many of the other lands bordering on the Mediterranean. It is characterised by heavy precipitation in the winter months and by long periods of low rainfall during the summer.

Because most of the precipitation along the Dinaric range is in the form of rain, the streams rising on the slopes have what may be termed a Mediterranean type of run-off, with their peak flows over the winter months and with comparatively low flows during the summer. Contrariwise, there is a so-called Alpine type run-off from the higher mountains of the north which is dominated by the high summer flows from the melting snows and by low flows in the winter when run-off is retarded by ice and snow formation.

2. Principal hydrostreams

The consequence of these geographic factors is that there are three or four concentrations of waterpower in Yugoslavia, each with its characteristic run-off pattern.

First, there are rivers which rise in the southern and the highest part of the Dinaric range where the heaviest rainfall occurs. On these streams the Drina, which flows inland to the Sava and the Danube, is the largest, and in fact the number one power stream of Yugoslavia. It has favourable sites for storage reservoirs and power plants, few of them developed. It has a modified Mediterranean type of run-off with large spring flows, a summer minimum, and a small peak in the fall. It is the easternmost of the rivers to have this secondary fall peak. On the Adriatic slope are the Neretva, Trebisnjica, Zeta, and Cetina, so-called karstic streams because of the limestone formations through which they flow. They have much the same run-off pattern as the Drina except for more pronounced winter peaks and summer lows.

The second concentration of power is the Drava, Sava and Soca, which rise in the Julian Alps in the extreme northwest part of Yugoslavia. The Drava is the nation's number two power stream. It has the Alpine pattern of run-off with large flows during the summer and minimum flows in the winter. The Sava and the Soca have a mixed pattern influenced both by the summer snowmelt and the winter rains from the Mediterranean. Nearby karstic rivers in the Planina add to the power potential of this area and to the potential winter energy production.

The Danube at the Iron Gates is the third concentration of hydropower in Yugoslavia even after allowing for allocation of half the potential to adjoining Rumania. Here the large and comparatively uniform flow of this large river can be utilized through a head of about 36 meters.

The many other rivers offer smaller but important opportunities for power development in almost all parts of Yugoslavia. There are the tributaries of the Sava flowing inland from the Dinaric range, the Vardar and its tributaries which drain Macedonia and flow to the Aegian, and the numerous karstic rivers of the Adriatic coast.

Altogether the hydro potential of Yugoslavia is only 3% developed. Although no reliable cost determinations have been made, it is generally concluded that the sites lend themselves to comparatively economic exploitation.

3. International waters

A considerable part of Yugoslavia's hydro potential is on rivers or lakes affected with an international interest. There are such boundary streams, for example, as the Drava and the Danube, which presumably can be exploited only by agreement with neighbouring Hungary and Rumania. The same is true for Lake Ohrid and Lake Prespa on the Albanian boundary, which offer economical storage for power sites downstream in Albania, but which can be developed only by joint arrangement between the two countries.

There are also the so-called "consecutive rivers" whose headwaters are in other countries (such as the Danube and the Drava) or which flow from Yugoslavia into downstream countries (for example the Danube or the Vardar). Any development which Yugoslavia may contemplate on these rivers within its boundaries can be affected by, or can have an effect on, the interests of the countries upstream or downstream. The total potential power of international streams can be maximised through international agreement on the optimum development plan.

Following is a tabulation of the principal rivers of Yugoslavia which are affected with an international interest:

a)

Boundary streams	Border country	Nature of international interest
Lower Mura	Hungary	Power
Lower Drava	Hungary	Power
Lower Danube	Rumania	Power, navigation flood control, irrigation and water supply
Bojana (lower Drim)	Albania	Navigation and flood control
Lake Ohrid	Albania	Flood control and power
Skadar Lake	Albania	Flood control and navigation
Lake Prespa	Albania and Greece	Power

b) "Consecutive rivers" rising in other countries.

River	Upstream country	Yugoslavia's interest
Drava	Austria	Power
Danube	Hungary and other countries	Power, navigation, flood control, water supply
Small streams in Banat	Rumania	Water supply and flood control
Nisava	Bulgaria	Flood control
Tributary of Crna Reka	Greece	Flood control

e) "Consecutive rivers" flowing from Yugoslavia to other countries.

River	Downstream country	Interest of downstream country
Danube	Rumania, Bulgaria and USSR	Power, flood control, navigation
Vardar	Greece	Power, flood control
Strumica	Bulgaria	Irrigation
Bozica	Bulgaria	Power and irrigation
Soca	Italy	Power, flood control
Black Drim and Lake Ohrid	Albania	Power, flood control, water supply, navigation
Lake Prespa	Albania and Greece	Power and flood control

4. Small waters

The smaller streams of Yugoslavia, including many small tributaries of the main rivers, are also the potential sources of a substantial amount of energy, much of it economically usable. It is estimated that up to 2 million KW of gross power exists in these small streams at sites which would support an installation of up to 1,000 KW. Several hundred such sites had been developed before the last war, for electric power production, another 500 had been exploited with turbines to provide mechanical power for the operation of mills, and perhaps 30 thousand primitive water wheels had been built to drive small village sawmills, flour mills and to provide motive power for other purposes.

Now, however, the small hydro sites are comparatively neglected. Some thinking has been given to the installation of perhaps a thousand such small power plants with a total installed power of perhaps 600,000 KW, for driving mills and providing a general electricity supply to villages. Considering how few villages are electrified and the remoteness of most villages from present or proposed power lines, it would seem feasible to provide at least an initial electric supply from many such local sources. In many instances, the power plant could be a joint development with a reservoir for general water supply, erosion control, flood prevention, or other purposes.

5. Total hydropower

The gross hydro potential of Yugoslavia has been estimated at about 125 billion kilowatt hours a year, and the net usable waterpower at about 50 billion KWh a year, based on the mean annual streamflow. This is about 10% of the European total and the same order of magnitude as the hydro potential of Sweden and Italy. It is exceeded in Europe only by Norway and France.

The potential hydro energy of Yugoslavia is also large with relation to its population and its land area. If completely utilized, the potential hydro would be equivalent to about 3,000 KWh a year per capita, a figure that is exceeded in Europe only by Scandinavia, Switzerland and Austria. A level of consumption of 3,000 KWh per capita per year has already been attained in Norway and is being approached in Sweden.

Because only 3% of Yugoslavia's hydro potential is now utilized it would seem that the nation could provide for its future growth largely from its hydro resources for at least several decades. If its requirements were to double each ten years (to employ one common measure of load growth) hydro could supply national requirements for four or five decades. If as seems more likely, industrial growth is more rapid, the period of hydro sufficiency would of course be shortened.

6. Energy exports

To the nations of Europe which are already utilizing the best of their hydro resources, the prospect of importing energy from Yugoslavia appears attractive. This is particularly so because of the Mediterranean pattern of Yugoslavia's streamflow, and its consequent ability to supply winter energy. Yugoslavia's hydro pattern thus is complementory to that of the Alpine rivers of central Europe. Consequently there would appear to be good reason to think in terms of a substantial energy movement northward for several decades or until such earlier time as Yugoslavia itself could use its entire hydro production. It also seems likely that there will always be an exchange of energy between Yugoslavia and central Europe to take advantage of the diversities in their run-off pattern.

Because of the current interest in this matter some further details may not be amiss. The attached diagram (Figure 1) illustrates the Alpine and Mediterranean type of streamflows.

The Alpine pattern affecting the streams of central Europe, the Drava, and to some extent the Soca and the Danube, is characterized by a discharge of only one-third of the annual mean flow during the winter months, and peak flows from May through August.

In the Mediterranean pattern of streamflow, which in Yugoslavia extends from the Soca to the Vardar and into Greece, three-fourths of the annual mean flow occurs in the winter months from late October to early April, with continued low flows during the summer and a small secondary decline in January and February when precipitation occurs to some extent in the form of snow.

The Alpine streams of Yugoslavia have a combined annual potential of about 140 billion KWh (source: ECE, Quarterly Economic Bulletin, Third Quarter 1952, page 33) and the non-Alpine streams of Yugoslavia a total potential of about 48 billion KWh (deducting 2 billion from the nation's total for the Drava). There is thus a three-to-one relation between physical capability of the two stream regimens.

This neglects for the moment the difference in the run-off pattern and in the comparative value of the summer and winter power. Winter power in Europe is costly to produce, whether in thermal or hydro plants. Any expansion of hydro plants will only increase the summer energy surplus. Expansion of thermal generation must be accompanied by heavy investment in the collieries and by constantly higher fuel costs.

As the diagram shows, Yugoslavia has two seasons when water can be stored to advantage. The first is in the late spring, when water can be

stored for release during the long summer drought, and the second in the autumn when water can again be stored, for release during the early spring for the benefit of central Europe.

Storage on the Alpine streams of central Europe will of course occur during the summer peak flows. Whether it is economical to over-install in the Alpine plants to utilize summer spills for return of energy to Yugoslavia is a matter beyond the scope of this inquiry, as is also the problem of achieving an economical balance between storage, thermal generation and transmission.

The wide diversity between the two water regimens suggests the obvious desirability of integrating the power systems which they each support. Because central Europe is an energy-deficient region it is more likely that there will be a net movement of energy north than of balanced seasonal interchanges.

This chapter, like others in this report, will be directed primarily toward the problems involved in improving and completing the inventory of resources. The present state of knowledge will be briefly reviewed in order to determine what the needs are for further work, following which the elements of a program for further exploration will become more evident.

In the case of hydro, the potential resources are determined by the systematic assembling of data on streamflows, precipitation, topography and geology. It is then possible to delineate overall plans for the utilization of the rivers for various purposes including power, and to formulate more specific plans for harnessing the falling water. We shall consider each of these steps in the pages which follow.

B. Physical Data

1. Hydrology and Meteorology

These two elements of hydropower analysis and engineering have fortunately been the subject of other recent UN-TAA missions to Yugoslavia. Meteorology was the subject of the mission of Mr. James M. Beall in the spring of 1952 (see his "Final Report - Fact-finding survey of the Hydrometeorological Service of the FPRY, 1 May 1952). The hydrological work of the Federal Hydrological Service was the subject of a mission by Mr. Max A. Kohler in early 1953, a report on which is in course of preparation.

Reference can be made to these two sources for competent treatment of meteorology and hydrology. What follows here reflects the special interest of this mission in the use of basic data for appraising the extent and character of the nation's hydropower resources. Although the matter has been discussed with Mr. Kohler he is of course in no way responsible for the facts or the recommendations which appear herein. Attention will be given principally to hydrology although the importance of meteorology and the relation between precipitation and streamflow is not intended to be minimized.

As a general observation it seems clear that there are sufficient data (when supplemented by data on precipitation) on streamflows, to permit an appraisal of hydro resources, and the formulation of general plans for their development. As in any country, there are gaps in the desired data which cause difficulties, but these usually can be overcome by correlation and extrapolation. At the same time, here as elsewhere, sufficient attention should be given to the improvement of hydrologic and meteorological data to permit more accurate estimates of energy resources and to facilitate and render more efficient the work of planning, design and operation of projects for the exploitation of this natural resource.

Much of the early data on Yugoslav rivers was for the general purposes of water control and utilization. At present, the power development program generally sets the pace for the hydrologic networks.

Water power has been utilized in Yugoslavia for many centuries through primitive water wheels used for wood cutting, grinding grain, iron forging and other purposes. Toward the end of the last century the first turbines were installed to provide motive power to paper mills and textiles factories. About the beginning of this century small hydroelectric plants were first built. The Tito hydroplant built on the Cetina River about 1912 its installed capacity of 62,000 KW was at the time one of the largest in Europe. Inasmuch as the early plants utilised only continuous flows (available all the time) hydrologic studies were often limited to the determination of minimum flows and to topographic surveying of river beds.

In Yugoslavia the meteorologic and hydrologic services are now united and centralised in the Federal Hydro-meteorologic Service known as SUHMS. This organisation tabulates and publishes weather and water statistics among many other functions, and maintains the national files and archives for such material. It is paralleled in each republic by a similar organization. The Republics actually operate the networks of stations and collect the data, copies of which are then sent to SUHMS. Special networks of stations are operated by navigation, agricultural, recreational, power or other interests either directly or through contractual arrangements with the hydro-meteorological services.

As might be expected, weather and stream-gauging stations were first established in the sections of Yugoslavia which were parts of old Austria-Hungary. There, as may be seen from (Figure 3), many gauging stations on the Drava, the upper Sava, and the Danube were established more than a century ago. Establishment of an observation network in Bosnia, Hercegovina and Dalmatia followed the annexation to Austria and grew especially rapidly after 1890. In Serbia the gauging stations on the larger rivers in the northern plains are about 100 years old. South of the Sava, and in Montenegro and Macedonia, only scattered observations were made under the Ottoman Empire.

Following the formation of Yugoslavia, in the period from 1923 to 1928, a network of stations were established throughout the country under the Water Board headed by the Russian engineer Bernacki working together with the French specialist Vignerot. In this period regular publication was made of rainfall and river stages. From time to time, also, measurements were made of the volume of flow at selected stations, so that by 1936-1938 it was possible to issue two publications on the duration and frequency of river stages with the corresponding discharge curves.

During World War II there was a consideration gap in observations for some stations, especially those in the mountainous areas. SUHMS has now issued yearbooks on hydrology for the war period so that the continuity of publications since 1923 is not interrupted. So far as meteorological data are concerned, however, the publications had stopped with 1940. This year, however, publications of the meteorological data has been resumed.

The present hydrologic network is shown in (Figure 4). A number of new stations were established during the last few years, many of them on the smaller mountain tributaries. A revised and expanded hydrologic network has been recommended by SUHMS after consultation with the power and other interests involved. Some of the new stations have already been established, including many in the karst regions. (Figure 5) shows the locations of the 105 new stations, all of which are said to have been carefully located where they can contribute most to the network, and some of which will replace older stations which were not so well located.

Figure 6 shows the location of the stations for the measurement of streamflows as contrasted to river stages. Present information on streamflows, especially at high water levels, is inadequate.

It is beyond the capability of this mission to comment on technical work of the hydrometeorological service. SUHMS and its associated organizations in the republics are aware of the present deficiencies, and are moving to overcome them. Suffice it to say that power engineers have expressed the need both for more records and better records. The present emphasis upon hydroenergy has naturally imposed a heavy and perhaps unexpected demand for hydrologic and meteorologic data on the reporting networks. The importance and the value of adequate data cannot be exaggerated. Constant adaptation to changing requirements will pay handsomely in more efficient and more productive engineering work.

Basic needs so far as power is concerned are for sufficient data for the planning of river development schemes and the design of individual power projects. At a later stage a somewhat different type of data will be needed for operation of the power system, in conjunction, of course, with other water uses.

Following are several points for improvement of the hydrometeorological data which are presently mentioned by the power engineers and which may be worth considering:

1. Expand the reporting network in accordance with the general plan worked out by SUHMS, modified to reflect any change in conditions.

2. Improve the quality of the observation, particularly on smaller streams that are subject to rapid fluctuations. This will require additional recording gauges.

3. Obtain better measurements of streamflow as contrasted to river stages.

4. More weather stations may be needed, particularly in headwater areas and especially for use in forecasting run-off for operating purposes.

5. Further studies should be made of the relation between precipitation and streamflow, both for planning and operating purposes.

6. The karst areas constitute a particular problem. Because of the proposed power developments in these areas the study and measurement of streamflows deserves the attention it is being given. Among the methods which can be used to advantage are geophysical and geological studies of underground structures, and chemical and other means for tracing the flow of water, including the use of radio-active isotopes.

7. Hydro engineers might find it desirable to review their plans with the Hydrometeorological Service at frequent intervals, to ensure that their most important needs may be considered and priorities established for the improvement of data in areas of particular interest.

The above proposals are advanced as an expression of the need felt by power people in connection with the appraisal and the development of hydro resources. They are subject to such specific views as Mr. Kohler may express on the conclusion of his work in Yugoslavia. It may be noted, however, that similar views were expressed by a temporary subcommittee on hydro power at the Energy Resources Conference in Belgrade on February 12, 1953. See Appendix 2.

2. Topographic mapping

Figure 7 shows the rivers where detailed topographic mapping has been undertaken, including establishment of river profiles and the minimum, average, and maximum river elevations of record. The year of mapping is also indicated.

The rivers basins of Slovenia and Croatia were surveyed by Austria-Hungary through its Army Geographical Institute and the Central Hydrologic Institute in Vienna. Yugoslavia undertook such surveys in the eastern part of the country in the period between the two wars. This was the period when Bernacki was establishing a hydrologic new-work. In Serbia he had to work with faulty topographic maps prepared under the Turks. Subsequent mapping has indicated that his watersheds and river profiles were not too accurately delineated. The most recent surveys have been made in connection with the preparation of the water use plans.

Following World War II a number of river basins have been mapped by photogrammatic methods, including the Drava, the Sava from Sisak to Belgrade, about 100 kilometers of canyon sections of rivers which are important from the view point of water power, and a number of shorter sections which were significant for one purpose or another.

Despite this work over the last few decades, there is still a need for further topographic mapping. The old Austro-Hungarian section including the Sava, Drava and parts of Dalmatia should be in part re-surveyed to insure the accuracy of the older maps and to bring them down to date. In the eastern part of the country the work which was started between the wars remains to be finished. Many of the smaller streams and headwater tributaries were never well surveyed, including the headwaters of such power streams as the Drina, Zeta, Bama and Vrbas.

The most important mapping is now being done by the Army Geographic Institute. This organization is mapping the entire country to a scale of 1:25,000 by photogrammatic methods combined with triangulation in accordance with international standards. The Geographic Institute made topographic maps of Yugoslavia before the war to a scale of 1:200,000 and 1:100,000.

More precise surveys needed in connection with river basin planning are made for prescribed areas and sections of the rivers by geodetic methods in combination with the photogrammatic surveys of the Army. Such work is done by the enterprise known as Georad, in Belgrade.

In the case of both Georad and the Geographic Institute the needs for their surveys are large and their work programs are heavy. Both organizations are impeded by lack of instruments, equipment, and trained personnel. Accordingly, it may be desirable to bring into proper perspective the value of an augmented topographic program to the inventorying and development of the nation's hydro resources.

3. Geologic Mapping

All of Yugoslavia is covered with geologic maps to a scale of 1:100,000 or 1:75,000. These maps and the related survey data have either been published or may be consulted in the archives of the National Geologic Institute. The mapping was done some years ago and is of uneven quality. Although all sections are generally satisfactory, others need to be improved.

More detailed geologic surveys are always made in connection with the preparation of the general river basin plans (osnova), to determine for example the suitability of the geologic structures for reservoirs, dams, tunnels or power plants. Still more detailed site explorations are of course needed at a later stage in connection with the preparation of final plans and design for a project.

Continued geologic investigations will be needed as the preparation of river basin studies progresses. Particular attention is being given to the karst areas in an effort to determine more exactly the underground movement of water and the suitability of upland valleys for storage basins. In this work many techniques are brought to bear including geology, laboratory analyses of permeability, and geophysical exploration. The full importance of detailed geological investigation of proposed dam and reservoir sites has not been sufficiently recognized. In this work as in some many other fields of activity, the shortage of modern instruments and lack of proficiency in their use is a considerable handicap.

4. General Water Cadasters

The first step of SUHMS after World War II was to re-establish its observation network and to resume the collection and publication of the raw data.

In Yugoslavia the next step toward the orderly assembly and analysis of the data so far as concerns its eventual use in connection with power, is the preparation of what is known as a water cadaster. A cadaster, as the term is used in Yugoslavia, is a systematic compilation of data for a particular purpose. The term is in such general use that it will be convenient to retain it in this report.

Water cadasters are an assembly and organized presentation of physical data for individual river basins, including data on the drainage area, land forms, and on the water resources. The water cadasters are thus the first organized study of a river basin. They stop short, however, of proposing plans for the development of the water resources.

The first water cadasters prepared by SUHMS after the liberation went beyond the scope as described above to the actual determination of the power resources of the river system. Based on this experience the question of the desirable scope of a water cadaster was thoroughly discussed in 1947 and 1948 by SUHMS, and the former Water Economics Committee in conjunction with power, flood control, irrigation, agriculture, water supply, civil works and others concerned. Agreement was reached that it was unworkable to include in one cadaster the basic studies with regard to all the above aspects. Accordingly SUHMS was henceforth to confine its work to the preparation of water cadasters of the scope outlined above. Its water cadasters could then provide the foundation for other more specialized and supplemental cadasters.

A water cadaster for a particular river will thus include topography, geology and other physical features of the drainage area, together with data on weather, precipitation, and streamflow. Other data on water temperatures and turbidity is also often included.

Special and supplementary cadasters of river basins are prepared on the following aspects of river basins:

Power cadasters - prepared by the power enterprises - to convert head and streamflow into the first approximations of hydropower.

Water supply cadasters - prepared by sanitary authorities - show the water supply and requirements for industrial and other consumptive purposes

Cadasters of underground water supply - prepared by water authorities

Flood control cadasters - prepared by water authorities to show flood control needs and works

Irrigation cadasters - prepared by water authorities and agriculture departments jointly - to show irrigation needs, soils, crops and other related data

River regulation cadasters - prepared by water authorities to show the bridges, highways, railroads, and other points and structures subject to damage from high water

Navigation cadaster - prepared by the department responsible for this function

Pollution control cadaster - prepared by the sanitary authorities to show the pollution and needs

Fish and wildlife cadaster - prepared by the agriculture department

Figure 8 shows the rivers for which general water cadasters have been published. In preparing these cadasters it was necessary to make use of all available source material, adjusted as necessary for consistency and uniformity. The deficiencies in the old Austrian data have become particularly apparent, as for example their lack of observation on average and maximum flows.

The general water cadasters on the Danube, Sava and Tisa were prepared by SUHMS under Pecinar's direction after 1948 when it was decided to restrict the SUHMS work to the general water cadasters.

Now that the power analyses are not made by SUHMS but by the several republics or by designated institutes, it might again be desirable to review the form and content of the water cadasters to ensure that they meet most effectively the needs of the power people with the minimum expenditure of time and money. Attention might be given especially to the analysis of variations in discharge over time, the records of extreme high and low flows, and of short-term fluctuations.

5. Power cadasters

Power cadasters are the first general studies of the power potential of a stream. The essential contribution is thus the multiplication of head and flow to determine the quantities of power and their distribution in space and time. The water power is usually shown for each section of the river, sometimes in units as short as one to five kilometers.

The first such computation was made by Bernacki in 1922 (see Appendix ___). He used the continuous streamflow, and streamflow available nine months of the year, but not mean flow.

At the second World Power Conference in 1936 a method was agreed upon for estimating the gross water power available in nature and without consideration for the possibilities of economical exploitation. This method was based upon the use of head and flow at 100% utilization with computations for power available 95% of the time, 50% of the time, and mean power available.

In 1945 a detailed study of gross water power in Yugoslavia was presented to the Planning Authority which showed a total gross water power in Yugoslavia based on annual mean flow of 125 billion Kilowatt hours a year. A summary of this work is attached in Appendix 3 and graphically shown in Figure 10.

Following is a list of the rivers for which power cadasters have been completed: (see also Figure 9):

Power cadasters prepared by SUHMS (1949-1950):

Main stem of Morava with tributaries
Western Morava with tributaries (Ibar)
Southern Morava with tributaries
Middle and lower Drina
Vardar

Power cadasters prepared by Cerni Institute (since 1950):

Cetina
Vrbas
Bosna
Lim
Uvac
Neretva

Power cadasters in preparation by Cerni Institute:

Una
Vardar

Power cadasters prepared by power enterprises in connection with their planning of hydro projects:

By Slovenia:

Drava River in Slovenia
Sava and main tributaries in Slovenia
Soca River and main tributaries

By Croatia:

Cetina
Dobra
Mreznica
Korana
Krka
Lika

By Bosnia:

Rama
Dana
Vrbas
Neretva

Two general problems remain with regard to the scope and content of the power cadasters. One problem is the avoidance of duplication as between the water cadasters and the power cadasters. Either because the preparation of general water cadasters has lagged behind the power cadasters, as may be seen from the above lists of the cadasters made to date, or for other reasons, many of the power cadasters have come to repeat the elementary physical data on the river basins which it had been intended to present only in the general water cadasters.

The second problem concerns the method of analysis of streamflow and hence of power potential, as used in some of the power cadasters now being prepared. The Cerni Institute has developed what it terms a "mean hydrograph" for presenting the variations in streamflow over time. By

observation the number of presumably typical peak flows in, say, a month, and their most probable maximum value, is determined. From each peak a recession curve is made based on the assumption that no further precipitation will occur during the interval. By this device the Cerni Institute attempts to show the probable timing of fluctuations in river flows, their shape, duration, and extreme values. The usefulness of such an idealized hydrograph has been the subject of discussion among hydro engineers, most recently in the energy resources conference held in Belgrade in February of this year. Although no conclusions were reached at this conference it is expected that the whole question of the contents and usefulness of power cadasters as now prepared will be further considered by the hydro engineers later this year.

C. Inventory of usable hydropower

1. General plans for the utilization of water resources (Osnova)

The desirability of comprehensive development of its river basins for all their uses is clearly recognized and widely accepted in Yugoslavia. It is reflected, for example, in the establishment several years ago of the Water Authorities and of their associated planning and design staffs. It is likewise quite deeply ingrained in the thinking of the power and other engineers who are working on plans and projects for the exploitation of the water resources of this country.

Water Authorities were established by Parliament in 1948 at the national level and in each republic. Their function was to assume the central responsibility for the planning and administration of the water resources of the nation. Without going into detail, their work involves the preparation or the general supervision of plans for the comprehensive development of water resources. A second function is the administration of the various laws pertaining to the use of water for consumptive, agricultural, industrial or other purposes. The water authorities also have technical staffs which engage in the design, operation and maintenance of drainage, flood control, irrigation or other works either for their own account or for local agencies or farm organizations.

In 1951 the water authorities were reorganized as part of the decentralization move. The staff of the national water authority was disbanded, and most of its work transferred to the water authorities in each of the republics. At the present time the essential work of the water authorities is not adequately recognized. Means are not provided to permit the performance of the broad responsibilities with which these bodies have been charged. Whereas they are the only bodies capable of assuming the broad function of guiding the broad development of the nation's water resources owing to adequate means at their disposal they are confining their efforts more and more to smaller projects and to administrative and operating duties.

Changes were made in the water authorities in 1953 but their exact nature is unknown to the writer.

The preparation of comprehensive plans for the best and fullest utilization of the nation's rivers is thus essentially the work of the water authorities. The first general concepts with regard to the over all utilization of the river are assembled in a report known as an "osnova." The osnova were to be prepared either by the Water Authorities or with their collaboration and approval. The federal water authority was engaged in the preparation of a comprehensive survey of the Sava river basin from 1948 to 1951, when the reorganization practically stopped its

work. The Sava river osnova is still in preparation. The Bosna River osnova has been completed and given limited distribution. The following osnova are also in course of preparation:

Zeta River
Cetina
White Drim
Vardar
Morava
Banat

The status of the preparation of these water use schemes is shown in Figure 11.

Other osnova have been prepared by other organizations such as the Cerni Institute. Among the osnova which the latter has published are the Lower Drina in 1948.

The osnova prepared by the Cerni Institute on the lower Drina in 1948 was more comprehensive than most. It included the basic data pertaining so the water and land resources of the Drina River drainage, a review of the principal problems and needs of the area as related to agriculture, water supply, irrigation, drainage, erosion control, reforestation, sedimentation, navigation, industry and similar aspects, and proposed a general plan for meeting these needs through the development of the water and land resources of the basin. Cost estimate were also provided, although plans were not prepared in detail.

The preparation of comprehensive development plans was initiated on a systematic basis in 1949 with the establishment of the water authorities. Their intention was that the osnova should be composed of two parts: 1/ essential, physical, economic, cultural and other data and 2/ a general scheme for the development of the water and land for all purposes. The development possibilities were to be outlined in terms of a long-term program in which the work could proceed by stages as the means and opportunities permitted. Again, however, it should be recognized that this general plan was for the purpose of providing perspective on the needs and opportunities for comprehensive development and that it did not elaborate the plans for any particular feature.

The agencies responsible for hydropower recognize clearly that their work can be done only against the larger frame of reference provided by the comprehensive development plans. Water development schemes must be available for the determination of the best over-all uses of the rivers and hence to indicate the amount of water available for power production. Such plans likewise indicate the possibility for the construction of reservoirs which have a multi-purpose value for other aspects than power as well as the possible conflict of power with other features.

All of this requires a systematic study of rivers and their drainage areas, for the purpose of formulating a comprehensive plan for the integrated development of the waters for their maximum values.

Because the water authorities have not been equipped to move ahead as rapidly as needed with the formulation of such over-all plans of development, the power enterprises have been handicapped in the preparation of their development plans. The problem was discussed at conference of power officials and water authorities at Maribor in October 1952. There it was again agreed how important the water utilization schemes are to the work of the hydro engineers, a priority order was worked out for the preparation of osnova for rivers for which no general development plans are yet available, and an arrangement was made whereby the power agencies will prepare the hydro portions of the osnova working in cooperation with the water, authorities, and the latter will thus be free to concentrate on the non-power portions of the osnova.

At the Belgrade energy resources conference in February 1953 the hydro people went farther to recognize that power plans could only be prepared against a background of knowledge with respect to the power needs of central Europe and the possibilities of energy export.

Until such time as the preparation of water utilization plans can overtake and anticipate the plans for hydro development, the latter must be prepared according to the best judgment of the hydro people and then submitted for review and approval by the water authorities. The latter will be forced to act without having the studies which can form an adequate basis of judgment.

So far as hydroenergy is concerned, then, it is important that the water authorities exercise the coordination vested in them for the most effective use of the nation's rivers. Failure or delays in working out comprehensive development schemes makes the work of hydro development both more costly and less certain. The osnova obviously cannot be prepared for all streams at once, and indeed, it is undesirable that they be prepared any farther in advance than they will be used. Hence the need for consultation between all interests on the relative order of priority for the various streams and the general scope of the more essential problems.

2. Power development plans

During recent years the practice has been introduced of preparing, upon completion of a water utilisation scheme, a preliminary plan for a power plant which will propose one or more alternative solutions and present the pertinent engineering and economic data and analyses.

The preliminary plan (idejni projekt) includes estimates of cost and feasibility. It is reviewed by competent authorities, and when and if approved is turned over to the design staff of the power enterprise for preparation of more detailed plans and cost estimates. It thus constitutes a proposal for development and serves as a basis for entering into contracts for supply of major equipment and for preliminary discussions with construction companies. Upon approval of the "idejni projekt", work is started on the so-called "main project" which includes details for construction purposes.

The above system thus provides for the following sequence of work:

Water utilisation scheme - osnova
Preliminary power plan - idejni project
Detailed power plan - main project

The detailed power plan (main project) contains sufficient detail to provide the basis for final authorisation to construct. From this point forward the preparation of any further details of design are usually entrusted to the construction organisation. The fact that this latter organisation does the building (without competetive bidding), the supervision of construction and the preparation of the final details of the design and cost estimates is, incidentally, one of the observed weaknesses of the present system. The principle of competition should be introduced as quickly as possible and the sponsoring organisation should retain supervision over construction.

The following table shows the installed capacity and annual production for power plants which have thus far been planned (including those now in operation or under construction) for the utilisation of the falling waters of Yugoslavia's streams, together with the status of work on each river as of March 1953.

The information contained in this table has been supplied by the design organisations of the several republics.

Most of these plans have been made since World War II. Although changes will undoubtedly be made in individual plants shown in the table as the planning work progresses, the total capability of these plants is believed likely to remain within the general order of magnitude of the figures shown, plus perhaps 10% to 20% to reflect the more effective use of waterpowers through more storage and integrated operation. Major shifts in the economic relation between hydro, coal, or other energy resources would of course change these conclusions.

The location of the potential developments is shown in Figure12. From this map may also be seen the rivers for which plans have not been prepared.

Section 3 below will describe in summary fashion the work which has been done in each republic on engineering plans for the development of water power. As will be apparent, it has not always been possible to follow the above ideal sequence of studies. On some rivers the power plans have had to be made prior to the formulation of general water use schemes.

NET USABLE WATERPOWER OF YUGOSLAVIA

KEY - PS Preliminary studies only

GP General project - now superseded by Osnova

O Osnova, or general water use plan

I Idejni project, or preliminary plan for a power plant

M Main project, or detailed construction plan for a power plant

	Installed capacity /MW/	Annual output /millions of kWh/	Status
SERBIA			
Upper Drina /Buk Bijela/	206.0	600	PS
Middle Drina	675.9	740	GP
Lower Drina	259.8	1,557	GP
Uvac	128.7	695	M 1 plant under constr.
Lim	366.7	2,414	O
Ljuma	120.0	287	O
Prizrenska and Bistrica	95.3	211	GP
Vlasina	113.8	388	M 4 plants under constr.
Western Morava	13.3	81	M 2 plants under constr.
Raska	6.0	29	M 1 plant under constr.
Timok	14.0	64	M 1 plant in operation
Studenica	36.0	159	O
Decanska Bistrica	32.0	196	GP O in preparation

	Installed capacity /MW/	Annual output /millions of kWh/	Status
Pećska Bistrica	24.0	149	GP 0 in preparation
Danube /Iron Gates/	800.0	5,350	M
Total Serbia	2,685.9	12,386	
CROATIA			
Recina	56.0	190	M
Vinodol system	88.0	200	M 1 unit in operation 2 units being installed
Lika and Gacka	148.9	808	O
Ricica, Obsenica, etc.	85.0	345	I
Krka and tributaries	98.8	487	O
Cetina	625.5	3,224	I
Ricica, Vrlika Tiholjina, to the sea	47.0	250	PS
Trebisnjica	250.0	800	PS[x]
Dobra, Mreznica, Korana	135.0	610	I, M
Kupa	80.0	400	PS
Una from 0 to 73	60.0	330	PS
Sava /navigation channel/	10.0	85	I
Semac /Vukovar canal/	43.0	230	I
Drava and Mura in Croatia	150.0	900	PS
Total Croatia	1,877.2	8,859	

[x]Preliminary estimate based on an Austrian plan made in 1916; later plans now in preparation which provide for storage reservoirs and full use of water will increase the installed capacity to 670 MW and annual output to 2.6 million kWh.

	Installed capacity /MW/	Annual output /millions of kWh/	Status
SLOVENIA			
Drava to Croatia	864.1	4,070.5	M
Sava	719.5	3,182.0	O
Soca	373.6	1,528.0	O
Smaller plants in the drainage area of the Sava	104.4	365.1	O
Smaller plants in the drainage area of the Soca	7.5	29.1	O
Cabranka and Kupa down to Kostela	33.2	127.4	GS
Reka /Timav/	37.0	165.0	GS
Total Slovenia	2,139.3	9,461.1	
BOSNIA & HERCEGOVINA			
Rama	80.0	660	I
Ulog, Neretva	60.0	490	M
Glavatičevo, Neretva	110.0	365	I
Ljuta, Neretva	19.0	157	I
Jablanica, Neretva	144.0	714	M under construction
Prenj, Capljina, Neretva	280.0	1,710	O
Sipovo, Pliva	26.5	138	I
Jajce I, Pliva	42.0	264	M under construction
Doljan, Vrbas	6.1	30.0	O
Doganovići, Vrbas	12.8	78.0	O
Han Skela, Vrbas	25.0	121	O
Jajce II, Vrbas	37.5	236	M under construction

	Installed capacity /MW/	Annual output /millions of kWh/	Status
Bocac, Vrbas	102.0	588	O
Trn, Vrbas	8.0	46	O
Laktasi, Vrbas	8.0	48	O
Ugar	13.5	80	O
Vrbanja	17.0	107	O
Slatina, Sana	20.0	77	O
Kljuc, Sana	60.0	239	O
Vrh Polje, Sana	18.0	78	O
Caplje, Sana	13.0	68	O
Bogatići, Zeljeznica	8.0	52	M
Mesići, Praca	2.8	20	M
Upper Trebisnjica /Bosna, Una, Spreca, Krivaja etc./		/not available/	PS
Total Bosnia & Hercegovina:	1,113.2	6,366	
MACEDONIA			
/No data available/			
Approximate Total	180.0	700	
MONTENEGRO			
Bjelosevina	3.6	6.2	M
Glusje	2.5	11.3	M
Liverovići	8.0	28.6	M Under construction
Zeta	216.0	1,164.0	M
Musovića Rijeka	1.3	7.7	M in operation

	Installed capacity /MW/	Annual output /millions of kWh/	Status
Glava Zete	4.8	30.9	M under construction
Slap Zete	1.5	5.6	M in operation
Total Montenegro	237.7	1,254.3	

R_E_C_A_P_I_T_U_L_A_T_I_O_N

SERBIA	2,685.9	12,386.0
CROATIA	1,877.2	8,859.0
SLOVENIA	2,139.3	9,467.7
B & H	1,113.2	6,366.0
MACEDONIA	180.0	700.0
MONTENEGRO	237.7	1,254.3
Other small streams - all republics	600.0	1,800.0
Total	8,833.3	40,833.0

3. Status of Power Development Plans

Historical review. A brief historical review may be helpful to an understanding of the present status of hydro plans and projects.

Immediately after the liberation in 1945, the Ministry of Economics organised the first hydro designing offices under its Department of Power and Energy. These offices included Electro Istok (electro-east), and separate offices in each of the Republics of Slovenia, Croatia and Bosnia.

In 1947 all work was centralised (except the separate offices in Slovenia and Croatia) in Electroprivreda (Electro-economics) in Belgrade. Its planning and design staff, headed by Ing. Cerni, was divided into working groups for the Drina, Neretva, Vlasine, Mavrovo, Zvornik, and possibly other major streams. In 1948 Elektroprivreda was given the status of a ministry.

In 1950-51 decentralisation resulted in the formation in each republic of a council for power and energy to handle hydro, coal and oil with a parallel council in the national government in Belgrade. The Energoproject of Serbia was formed to take over the design and planning work for this republic, and the Hydroelektroporjekt was established in Bosnia. The design staffs of Slovenia and Croatia continued as before. It was not until 1952, however, that Macedonia formed a hydro design staff, while in Montenegro there is still no hydro engineering organisation, this republic continuing to contract with Serbia and Slovenia for its project designs.

There is now some sentiment for a stronger measure of central coordination, possibly through the formation of an association of the electric enterprises of the several republics. During the past several years, project planning has been on an isolated and independent basis. The principal exception has been in Croatia and Slovenia where a number of projects like the Cetina and Vinodol were planned on the basis of integration with the Alpine-type run-off of the Drava.

Serbia: The Zvornik project with Drina River is under construction. Several projects designed by Energo-Project Serbia are going into the final stages of design with a view toward early construction. These include Kokin Brod (on the Lim River) and the Zeta Project in Montenegro.

The general studies made in 1947 for the Drina and the Lim may now be completed by the Cerni Institute by the addition of the non-power aspects. This Institute will also prepare osnova for the upper Drina and tributaries.

The cadasters for the non-power aspects of some of the smaller rivers, and particularly the agricultural cadasters, are being completed by the Water Authority of Serbia for the White Drim, the Morava River and tributaries and certain other streams.

Power studies remain to be made for the Ibar River and the Morava River and tributaries. The above studies will increase the total annual production from the 12 billion kilowatt-hours a year shown in the table which is attached to about 17 billion.

Further work on plants for which preliminary designs are prepared will probably result in some changes in design, but not a great deal of change in the total installed capacity. It has already been stated that the work thus far done has been on the basis of isolated plant operation without reference to the integrated operation of reservoirs and plants.

Comment has been made that the Energoprojekt is so completely occupied with final design for plants being prepared for construction that its staff is unequal to the further task of preparing preliminary power plans for rivers not yet studied.

Croatia: The planning and design staffs have proceeded on the basis of obtaining a continuous annual production for the Croatian power system as a whole. For this purpose it has been assumed that some summer energy could be obtained from the Drava River in Slovenia to complement the winter production at Vinodol and the Cetina.

Now with the prospect of finding an export market for surplus winter energy, plant designs and power system plans should be reviewed for the purpose of achieving a fuller utilization of winter streamflows. Both storage reservoirs and installed generating capacity can probably be increased to advantage. This may raise the total output from the 8.8 billion kwh a year shownin the table to perhaps 10 billion kwh.

As the table indicates, only preliminary studies have been made for the Drava and the Sava in Croatia.

Slovenia: Systematic studies have been in preparation since 1945 for hydro plans for Slovenian streams. At least preliminary work has been done on all the major rivers including the Drava, upper Sava and the Soca. Until recently at least, the planning has been based on the assumption of achieving a balanced annual energy production for an independent Slovenian power system. This task is facilitated by the considerable diversity between the principal streams.

If the assumptions are to be changed and the Slovenian plants operated as parts of a larger system, plans should be reviewed. As in Croatia, storage could be increased and larger generator capacity installed. Winter energy can be obtained by advancing the development of the Soca and other streams in the west.

There is agreement between the plans of Croatia and Slovenia with regard to the use of summer energy from the Drava to balance winter output in other streams. It was on this basis that the 110 kv interconnection was built from Maribor to Varazdin.

Bosnia and Hercegovina: The design organization established after the liberation worked on plans for such large projects as Jablanica and Jajce which are now in construction, and on preliminary water and power schemes for the Neretva, Vrbas and Sana. The current status of work is shown in Table above. Inclusive as this list is it does not

include the streams of the karst fields, the upper Trebisnjica, karstic tributaries of the Neretva, non-karstic tributaries of the upper Neretva, some tributaries of the Drina, Bosna River and tributaries the Una and the Unac. Power in these streams can increase the total shown in the table by about 40% from 6.3 billion kwh to perhaps 9 billion kwh per year. Bosnia proposes to complete at least preliminary power plans for all its rivers within the next several years.

Most plans and designs for this republic, too, have proceeded on the assumption of isolated operation and without considering the possibilities of integration with neighboring systems. Recently consideration has been given to redesign of some plants for larger winter production for the purpose of export.

Macedonia: Some years ago a small engineering staff in Skopje prepared plans for the Mavrovo project which is now in construction. The figures contained in the table include only Mavrovo and a few smaller projects.

Lacking a planning and design staff of its own, Macedonia has contracted with the Cerni Institute to prepare a water utilization scheme for the Vardar River over the next three years, and with other organizations to prepare plans for the Black Drim and parts of other rivers.

Inasmuch as erosion control, flood control, and summer irrigation are of primary importance in Macedonia, large storage reservoirs are planned to carry water over into the summer season. Power production is thus likely to be shifted into the spring and summer months. Interconnection with Serbia, Montenegro and Greece would permit advantage to be taken of seasonal diversity in streamflows.

Total usable hydro production, upon completion of the plans for all the streams in Macedonia, is expected to reach 2 to 3 billion kwhr a year.

Montenegro: This republic, like Macedonia as yet has no planning staff of its own. The Energoproject of Serbia has undertaken the responsibility for the design of the Zeta project. Designs for this relatively large project are said to be completed as well as for the other smaller projects included in the table.

Other possible developments on the Morava, Cijevna and the tributaries of the Drina /Lim, Tara and Piva/ are of considerable magnitude. The Drina River tributaries however will probably be planned by Energoproject of Serbia and have been included in the 17 billion kwhr potential production show for that Republic.

Summary: Thus it seems probable that when plans have been completed the usable waterpower of Yugoslavia will total in the neighborhood of the 50 billion kwhr figure that is generally quoted. This total will depend on considerable amounts of storage and completely integrated operation.

The proportion of the nation's hydro potential which can be economically developed may be maximized through such means as the following:

1/ integration of all hydro plants into a single national power network to take advantage of diversity in streamflow, diversity in loads, and other system factors;

2/ construction of additional storage reservoirs over those which had been originally planned on the basis of isolated operation;

3/ possible use of thermal plants to supplement seasonal storage and to firm up hydro during low-water years;

4/ export of winter and other surplus energy.

On the basis of the present knowledge it is not useful to attempt to guess whether the 50 billion kwhr figure will be appreciably changed through operation of the above factors.

4. Commentary on the planning and design of plants for the utilization of the nation's water resources

Discussions with hydro engineers have revealed how uncertain is the basis on which many of their plans and designs have been prepared. Their engineering work has been sound in the sense that valid solutions have been reached from the facts at their disposal. But they are now faced with the task, in many instances, of reviewing their plans to fit them into a different set of assumed conditions.

In a word, engineers cannot make good plans for an individual plant unless they have at their disposal the general water utilization scheme for the river, on the one hand, and a general power system plan, on the other. Engineers have often lacked data on power loads and on the alternative possibilities of power production in thermal plants. Accordingly they have been unable to reach valid conclusions with regard to such matters as the economical size of reservoirs and generator installations.

To be more specific, the following comments are ventured:

1 - Water use schemes should be expedited. Lacking the background that such general plans can provide, power engineers are faced with decisions (for example on the diversions of water from one drainage area to another, as in the case of the Lake Bohinj plan) without the possibility of competent guidance.

There may also be significant conflicts between power and non power interests as in the case of the Belgrade Bar railroad now under construction which would run through the proposed reservoir sets on the upper Drina. Priorities for completing the river basin studies should be established, on a national basis, with a view towardmeeting the needs of power, as well as other interests.

2 - Agreement should be reached on the integrated operation of a river system, i.e., on whether all river projects (for power, flood and erosion control, navigation, general water supply, irrigation or other purposes) are to be operated for combined maximum benefit, or whether each project is to be operated on an individual basis without relation to the water uses.

3 - Similarly, understanding should be reached as to whether power facilities are to be operated as an interconnected and intergrated system, and if the latter, the extent and the characteristics of the system. There seems to be little doubt about the formation of a power system within each republic, but there is apparently no explicit agreement with regard to integration on a national basis. It may also be only a matter of time until there will be one or more interconnections between the Yugoslav network and the networks of neighboring countries.

4 - Means should also be found for the concurrent consideration, so far as the electric system itself is concerned, of generation, loads and transmission in order that the optimum engineering solution may be reached. For this purpose there is needed what may be termed a system engineering staff which can be charged with this task on a national level.

5 - Thermal generation, based probably on the use of solid fuel wastes, should also be brought into consideration. This will require further study of the availability and cost of solid fuels, which in turn will hinge to a large extent on national policies with regard to the conservation and exploitation of solid fuels.

6 - Economic analysis should be strengthened. Owing to the almost complete absence of competent cost estimates and records it has been impossible, up to the present at least, to make analyses of the comparative costs of various river projects or of alternative engineering solutions. Similarly, it has been impossible to determine within a reasonable margin of accuracy, the magnitude of the investment which must be made to develop those resources. When a means has been found for making reasonable competent cost estimates it will also be possible to make studies of the economic possibility of projects, something that has not been possible up to the present.

7 - Means must be continuously available for providing guidance and direction with regard to national policies and programs which have a bearing on water and power developments. e.g., policies with regard to the conservation and development of resources, and policies on energy exports, programs for economic and industrial development, a timetable for development of water resources, programs affecting the availability of manpower, equipment materials and investment funds; national practices with regard to prices and costs, and defense considerations to be followed in the planning of water and power projects.

D. Recommendations

Following are some observations which may serve to summarize and correlate the views expressed throughout the above sections on hydropower.

1. Comprehensive planning for the development and utilization of the water and land resources of the nation's river basins should be strengthened. The principle that the rivers should be developed for all their uses is generally recognized. Investigation and planning for water use must move forward simultaneously and in proper sequence with the related land aspects. Only on this basis can the hydro engineers know how much water they can utilize for power production, can consider the joint use of reservoirs and other structures for multiple purposes, and can consider such limiting factors as conflicts with communication and transportation lines or other improvements.

The priority in which the nation's rivers should be considered for river basin studies, and their general timing of these studies, should be established and occasionally reviewed. Such priorities should be based on the relative needs for various uses of water and land resources, the status of the basic data, investigations, and the national investment program.

Presumably this is the work of the Water Authorities, both in the republics and the national government. Fullest support should be given to the work of these bodies, and fullest recognition to the public policy which guides their actions. Any lag in their work as compared with the emphasis on energy resources development should be brought into balance.

As in the case of the general coordination of energy resource programs as a whole, there is undoubtedly much to be gained by the exchange of experiences and views between Yugoslav administrators and professional people and their counterparts in other countries who are engaged in river basin development. Any proposals for such interchanges should be given high priority.

2. Hydrologic data are sufficient to permit a general appraisal of energy resources, but should be improved in several respects including (a) expansion of the reporting network in accordance with a carefully considered set of priorities, (b) better quality of observations particularly on the smaller streams, (c) better measurement of streamflows as contrasted to river stages, and (d) with continuing special attention to the karst areas.

3. Meteorologic data can be improved through such means as the establishment of more weather stations, especially in the higher elevations, and through further studies of rainfall run-off relations.

4. Topographical surveys: Continued topographic surveying and mapping is needed both to complete areas not yet surveyed and to correct older surveys. Based on the information that this work is being centralized in the Geographic Institute of the Army, the work of this organization should be supported. Geodetic surveying is also needed both in conjunction with the photogrammatic work and for more detailed studies of certain areas where water use projects are under study. More photogrammatic equipment and trained personnel can probably be used to advantage.

5. As to geology, continued investigations of river basins will be needed as the work of preparing power development plans progresses. Preliminary water use planning requires general explorations to determine the suitability of sites for reservoirs, dams, power plants and tunnels. The use of geologic methods in explorating the karst regions has already been mentioned. Reference is made to the forthcoming report of the mission headed by Mr. Karpov with respect to the need for more detailed geological explorations of foundation conditions.

6. Water cadasters: As already suggested, it may be desirable to review the published hydrologic records to ensure both that they are sufficiently complete and that there is the proper division between them and the more specialized cadasters prepared by other agencies (e.g. the power cadasters.)

7. Power cadasters: It may be also desirable to review the purpose and content of the power cadasters. The problem of avoiding duplication between the water and power cadasters has been mentioned, as also the problem of making the power cadasters serve the most useful function. It may be possible at the present stage to telescope the work which was necessary at an earlier stage with a consequent saving in time, money and effort.

The whole problem of the method and scope of reports on hydro resources is currently under consideration by a temporary committee established by the Energy Resources Conference which was held in Belgrade in February.

8. Power development plans: The practice of arriving at final development plans for hydro development in sequences, starting with the general water use scheme and ending with the detailed project design in both sound and in conformity with general practice elsewhere.

The fact that only preliminary power development plans have been worked out as yet for most rivers, coupled with the pressure for tangible accomplishment, suggests the desirability of maintaining at all times a general agreement on the order of priority in which the further and more detailed plans will be undertaken and the wisdom of concentrating the engineering skills and other means available on the areas of greatest interest.

Attention has been directed in the text above to some observations with regard to possible improvements in the work of power development planning. These included:

(a) Provision of a broader frame of reference to hydro engineers to include such factors as objectives of development, the time-table of development, the assumptions to be used with respect to the availability of men, materials equipment and other means of constructions, the assumptions to be used as to whether all river improvements will be operated as a single integrated river system for maximum overall effectiveness, assumptions with regard to the integrated operation of the nation's power network, and the military or other non-power considerations which should enter into the plans.

(b) Better analysis of costs and other economic aspects. The almost complete absence of good cost estimates and cost records for power plants and hydro developments has been noted, as also the importance of cost analysis as a tool for engineers and administrators. Similarly, the economic benefits

of proposed developments should be considered and analysed more effectively in order to ensure that the most economically desirable solution is reached.

(c) There might well be established what would amount to a central system engineering staff for the enterprises of Yugoslavia, possibly under the sponsorship and general direction of an association of electric enterprises of the several republics. This staff could consist of several well-qualified engineers who would be charged with the review of plans prepared by the several existing institutions and enterprises in the light of conditions that would prevail in an interconnected and integrated network, and the rendering of advice and guidance to the design engineers in adapting their plans to system needs.

This system engineering staff would bring together most effectively the situation with regard to power loads, power generation, and transmission, including the operation of reservoirs and thermal plants. It could likewise bring into consideration interconnection with foreign systems to the extent appropriate.

An approach toward the above objective was made at the Energy Resources Conference in Belgrade in 1953 in the recommendations that a committee be established to assemble estimates of energy requirements and schedules of generation, and that another committee be established to prepare plans and engineering standards for an integrated transmission network.

Such working committees can be of great help in assembling data and effecting interchanges of views. Nevertheless it would also seem to be necessary to form a small staff of engineers who would be charged with the responsibility of guiding the development of a national integrated power network. Such a responsibility cannot be assumed by a committee, although committees can assist, as already suggested, in the preparation of data, as also in providing general policy guidance.

What is called for is consistently top-grade engineering analysis of a complex series of plans and designs for power plants and lines which must be considered against a constantly changing background of present and estimated future conditions. It is submitted that work on the hydro potentiality of Yugoslavia has progressed to the point that such a group of working engineers can make a real contribution to the sound development of hydro resources.

With respect to the preparation of plans for power developments, it is always possible to gain from exchanges of views and experience with professional and administrative personnel in other lands. Following are some of the phases of this work which suggest themselves in this connection:

- Power system development; the broad aspects of the preparation of plans for the expansion of the power systems including hydro and thermal generation, power utilization, economic analysis and financing.

-Power system engineering: methods and technique used by power system engineers in arriving at overall plans for power system development and operation, including the concurrent consideration of generation, loads and transmission.

-Power requirements: techniques of preparing load estimates including source of data on future requirements, degree of accuracy desirable in longer-range forecasts, period to be covered.

-Hydro generation: methods and techniques for analyzing the capability of hydro plants, for working out the capability of integrated systems of hydro plants and reservoirs, and of preparing plans for the coordinated operation of such a system under assumed conditions of load.

-Transmission planning, including the analysis of power movements over an interconnected system and the solution of problems observed.

-Economic analysis of power system construction and operation, including cost determination estimates of benefits, analysis of economic feasibility and possibly also problems of financing and repayment.

It is likely that many, if not all of the above phases of power system engineering and analysis, will enter into the joint studies of power exports from Yugoslavia to central Europe which are about to be undertaken under ECE auspices. Accordingly the desirable exchanges of views and experiences with foreign engineers and administrators can perhaps be provided during the course of the ECE work. On the other hand, it may be found desirable to anticipate or to supplement the foreign contacts made in this connection. In any event, any proposals advanced by Yugoslavia for foreign contacts in the above or related phases of power system development will be deserving of prompt and sympathetic consideration.

It is possible also that laboratory equipment and instruments and calculating devices may be useful or highly necessary in connection with the above. If proposals are advanced for technical assistance in the supply of such instruments and equipment, including training of technicians in their use, they can be considered on their merits at the time.

II. FOSSIL FUELS

A. Summary Perspective

The fossil fuels - oil and gas, coal, and oil shales - constitute the second great energy resources of Yugoslavia. Based on present knowledge, the fossil fuels are quite extensive although not as predominant as in the industrial nations of Europe. The largest deposits are the lignite which quite extensive are of such low calorific value as not to be economically usable in their native state. Progress is being made by Yugoslav scientists in techniques for their treatment and processing.

Productions of coal is low, about one-third of a metric ton per capita per year, but is growing. Oil is not produced in sufficient quantities to meet domestic needs, there is no substantial exploitation of natural gas, and none yet of oil shales.

Because the author can claim no technical competence in fossil fuels, it has seemed best to restrict the contents of this section to an assembly of the most useful materials available with a view toward providing perspective on this energy resource and particularly on the status of knowledge with regard to reserves. Only limited expressions of judgment are made as to the main problems which still remain for attention and the most likely avenues for further exploration and investigation.

The need for further work on the inventory of resources is reflected in the report of the Commission for Fossil Fuels to the recent Energy Resources Conference in Belgrade, a copy of which is attached as Appendix 5. The problem of classification of fossil fuel reserves was discussed at this conference by Director Mikinčić of the National Geologic Institute. His statement is attached as Appendix 6.

B. Geology of Fossil Fuels in Yugoslavia

Although complete information is not available, it is possible on the basis of present knowledge to present the main elements of the geology of the fossil fuels in Yugoslavia. From this analysis there will appear more clearly the further studies and explorations which should be made to extend or to complete the existing knowledge of these resources. It will be helpful if at the start we recollect that coal and the primary bituminous shales are of sedimentary fresh water origin whereas oil and gas are the remains of marine algae which grew in warm salt seas.

Apart from the small known deposits of hard coal of the Jurassic and Cretaceous periods found in the Carpathia-Balkanic mountain arch, all the coal deposits of Yugoslavia are of Tertiary origin. Most Tertiary formations contain browncoals or lignites.

Coal appears in the Tertiary of the Dinaric Alps in three bests: the northern or inland belt (Podravina, Posavina), the middle belt along the mountain ranges (Trbovlje, Lasko, Bosna, Morava), and a coastal belt (Rasa, Siveric, Mostar). The salinity of the coastal belt of the Panonian shores disappeared during the formation of the Dinaric ranges. That means that the older Tertiary strata of the Panonian Belt may be found to be oil-bearing and should be explored.

During the older Tertiary period conditions existed in the shallow waters of the shores of the Dinaric ranges along the Panonian Sea that favored the formation of oil-bearing deposits.

Later this area experienced conditions favorable to coal formation. Therefore it is believed that oil, gas, and secondary shales may be found in the deeper marine sediments, and coal in the upper fresh water deposits. This conclusion was apparently only recently reached. Thus the Eocene formations of Majevica are oil-bearing whereas toward the west they are overlaid by the Miocene deposits which contain the Kreka lignites. Methane, salt, and oil have been found in the latest drillings below the lignites.

The great Tertiary basin on the Save plain from Vrbas to Banja Luka and along the new railway to Doboj and the Kreka Basin and Zvornik, originally was a salt sea and therefore may contain oil below the coal-bearing formations. This basin extends further to the Western Morava Valley from Cacak to Aleksinac where oil shales have been found. Accordingly it would seem that the bituminous shales of the West Morava, Kolubara, Trstenik and Aleksinac were originally part of the older marine sedimentary oil-bearing strata.

The situation is clear in the older Tertiary formations of the Sava and Drava plains in which numerous oil-bearing strata have been found by geophysical means. Here only the erosian remnants of the older formations are not oil-bearing. Geophysical explorations are appropriate to these plain areas, by deep seismic methods for oil,

and shallow seismic methods for coal. The latter is indicated particularly for the coal deposits along the Drava, along the Sava at Brod and to the south of Sava. The geophysical results can be confirmed at suitable locations by drilling and analysis of the cores for physical, chemical, and micropaleontological properties.

The middle or mountain belt of the Dinaric ranges such as the Plevlje Basin, Ivangrad, and others in the karst area, as well as Kosovo and others in Macedonia, probably contain only fresh water sediments where coal and primary bitumenous shales are to be found. These coal formations are of great importance and deserve further exploration by topographic, seismic and other means.

The geology of the inner or coastal belt along the Adriatic shore is entirely different. Investigations carried out recently in Montenegro indicate that the oil strata along the coast are older than the Tertiary, being marine deposits from the younger Paleozoic era. It is first necessary to establish the existence of favorable structural conditions for the storage of oil. It is known that the Dinaric mountains were formed by the folding and the thrusting action with pressures from the Panonian basin toward the Adriatic. It seems unlikely that the structures could have remained sufficiently intact along the backbone of the Dinaric mountains. Along the Adriatic coast where the folded Dinaric masses overlie the older formations, conditions favorable to the preservation of the oil deposits are believed possible. Oil found in Albania in Tertiary strata is thought to have migrated from deeper Paleozoic formations. Similarly, asphaltic outcroppings in the limestones north of Mostar and in the Dresnica Valley are the result of oxidation of crude oil from the deeper and older structures. Also the bituminous shales near Sinj and at other locations are believed to be of secondary origin, the result of migration of oil from the adjacent Paleozoic formations.

Oil explorations along the coast should first be carried out where the older formations are overlaid with only a thin covering of the younger Dinaric masses. This condition is found near Bar, Dubrovnik, Popovo Polje, Vrgovac, Sinj, and parts of the Velebit and of Istria. Here is nearly impossible to apply geophysical methods of investigation. Detailed geological explorations are necessary, followed by deep drilling.

In summary, current geological thinking is to the effect that geological explorations should be continued on a broad regional basis, supported by geophysical explorations in the northern plains, and by deep drilling in the middle and coastal belts of the Dinaric mountains.

Yugoslav geologists express the expectation that upon completion of these explorations, known coal reserves may be increased from 21 billion to about 30 billion tons, and the 30 million tons of petroleum reserves may be trebled. The writer is not able to express any judgment on this matter.

C. Oil and Gas

1. Preface

The purpose of this section, as indicated above, is to provide a general perspective on the status of information on oil and gas resources, for whatever guidance this may be to a petroleum specialist in determining the further steps to be taken to add to available knowledge of this important energy resource.

The bulk of the data which follows has been supplied by the oil and gas enterprises of Serbia, Croatia and Slovenia. The geological and geophysical institutes and the exploration companies have also provided information within their respective spheres of activity and interest, as has also the Petroleum Institute at Zagreb.

The production of petroleum is now in the hands of local state-sponsored enterprises in each republic, as follows:

Naftagas, Zrenjanin	(Serbia)
Naftaplin, Zagreb	(Croatia)
Nafta Lendava	(Slovenia)
Nafta Tuzla	(Bosnia)
Nafta Ulcinj	(Montenegro)

The Institut za Naftu, Zagreb, performs engineering and chemical work for the oil industry on a consulting and contractual basis.

The several geological and geophysical institutes engage in consulting and exploratory work by agreement with the oil and gas enterprises.

2. Historical perspective:

Oil and gas are the youngest of Yugoslavia's energy resource industries. Not until the second World War were oil and gas discovered in significant quantities. Only in the post-war years has production attained any significant volume. Small as present consumption of petroleum is in Yugoslavia, however, domestic production is able to supply only a minor part, with principal reliance still being placed on imports. Hence the interest in the discovery and exploitation of new wells, and hence also the attention being given to possible alternative sources such as oil shales and lignites.

At the beginning of the century traces of oil and gas were discovered near Tuzla in Bosnia, and Peklenica in Slovenia. During World War I gas wells were drilled in Slavonia. Gas was also found in the Banat north of Belgrade. Production from these early discoveries was of no importance except for a well at Bujevica in Croatia where four million cubic meters of gas were produced per year. Between the wars only a few

local explorationswere undertaken, although geological studies were continued on a more or less systematic basis. Oil production was only a thousand tons per year and natural gas was exploited only for a few local uses.

When the Germans occupied the country in World War II they conducted geophysical explorations over large parts of the northern plains through their German firm Seismos of Hanover. Similar German explorations were made of the Panonian Basin in adjoining areas of Austria, Hungary, and Rumania. The attached map (Figure 13) shows the extent of these war-time explorations. Copies of the German records and maps which remained in the hands of the Yugoslavs after the war have served as a basis for the present drilling and exploratory operations.

The Germans were able to exploit the Slovenian and Croatian fields only to a limited extent, their total war-time production being estimated at only 66 thousand tons. They were preparing to drill their first well in the Banat when the war ended.

After the liberation in 1945 the Yugoslavs continued with both exploration and exploitation, using the German maps as a guide. Structures as indicated by the German maps were further checked by geophysical means and by drilling, and production was brought up to the present level of about 160,000 tons per year. Lacking both experience and equipment, however, the Yugoslav engineers and scientists have been greatly handicapped in what to them was a new line of endeavor.

Recent structural drilling on the Adriatic coast of Montenegro is said to have found favorable indications for the occurrence of oil in the older Paleozoic structures along the entire coast encourages the view that large new oil-bearing areas may be found here. Whether this view is correct or not, it indicates that the petroleum geology of Yugoslavia is young and that only the beginning has been made in systematic exploration.

3. Explorations

Thus the traditional tools of petroleum exploration (geology and drilling) have been supplemented in Yugoslavia by the modern geophysical techniques. As already suggested, explorations have for the most part been confined to the tertiary formations of the northern plains bordering on the Panonian Basin, although interest is now extending to the inter-Dinaric areas and the Paleozoic formations of the Adriatic coast.

The geology of Yugoslavia so far as it relates to petroleum has been described above. Further statements on explorations in Croatia and Slovenia are attached as Appendixes 7 and 8.

a. Serbia - Geological mapping of Serbia has been undertaken during many years by geologists such as Petkovic, Cvijic, Zujevic, Lukovic, Pavlovic and Laskarev, and by the Geological Institutes of Yugoslavia and the several republics.

The extent of the geophysical explorations made by the Germans during World War II is shown in Figure 13. As may be seen, these explorations covered part of the plains area north of Belgrade known as the Banat and the Backa. The German maps show about 30 anticlines in the 600 square kilometer area which they explored. As already indicated, the Germans drilled at Velika Greda but were forced to withdraw before obtaining any results.

Explorations were resumed in 1949 by the former Company for Oil and Gas Exploration and Production, and have been continued by its successor company, Naftagas Zrenjanin, and by the Geophysical Institute of Serbia. Thirteen anticlines have been verified by geophysical means and five by structural drilling. Gravimetric explorations are being continued, with other verifications in prospect. Owing to the lack of seismic apparatus, only the gravimetric, and magnetometric methods are used. Recently, geophysical explorations have been extended to the area south of the Sava River and including the Western Morava valley. Some nine anticlines have been found here, one of which near Rankovicevo has been verified by structural drilling.

An area of 13 square kilometers has been covered by deep drilling in the Velika Greda gas field where reserves of an estimated 1,6 billion cubic meters of gas are said to have been established. The gas contains 1.8% of hydrocarbons by volume. Inasmuch as the boundaries of the field have not been determined, the total reserves may be expected to be increased as the drilling continues. Naftagas, Zrenjanin, has supplied the following statement on this matter:

> "Since the structure of Velika Greda is continuous southward, with two more anticlines at Jermenovci and Lokve which probably form a single structure with the one at Velika Greda, the B and C reserves are probably more than 10 billion cubic meters of gas. This assumption is confirmed by the fact that the first well drilled at Jermenovci resulted in an oil-bearing stratum more than 100 meters thick. It must be mentioned that the well was not completed owing to a lack of tubing and Christmas tree equipment. If we consider the depth of the Velika Greda wells, the above supposition that there is a connection between both structures is quite real. That means that the area which is interesting from the economic standpoint does not cover only 13 square kilometers but about 70 square kilometers. This latter area has been taken into consideration in computing the reserves. B and C reserves of carbon dioxide have been estimated at 5 billion cubic meters with a 10% methane content. The estimate is based on the deep drillings at Becej".

Explorations should be extended, according to Naftagas Zrenjanin, over the tertiary plain known as the Vojvodina (north of Belgrade), most of the valley of the Morava River and its tributaries, the area south of Belgrade, and other scattered areas such as Negotin on the Danube in northeastern Serbia.

Naftagas' immediate program calls for geologic mapping in 1. the vicinity of Negotin, 2. the area south of Belgrade, and 3. the area near Vranje. The Negotin area on the Danube in eastern Serbia is structurally connected with the Rumanian oil fields. Geophysical work will be directed toward verifying the German maps of the Backa and other areas north and east of Belgrade. Deep drilling will be continued at Velika Greda-Jermenovci and Lokve for the production of oil and gas, at Zrenjanin for gas, and at Rankovicevo for gas.

Deep drilling is being undertaken in the large anticline in Backa near Becej where three wells have been drilled, and carbon dioxide and methane have been found. Exploratory drilling at other locations can be undertaken only when the rigs can be spared from producing fields.

b. <u>Croatia</u> - The extent of the wartime geophysical explorations by the German firm "Seismos" is indicated in Figure 13. On the basis of these explorations, together with geologic studies and other pertinent data, the relative value of the several indicated structures was appraised and a program of drilling was determined.

As stated by Naftaplin Zagreb, the work done to date is as follows:

"<u>Sumecani (central Kriz structure)</u>

In the middle part of the Kriz structure 84 wells have been drilled to date. Of these, 65 were positive and 19 negative. For further contouring of the field it will be necessary to drill more wells.

<u>Bunjani (eastern Kriz structure)</u>

In the south-eastern part of the Kriz structure, the existence of oil-bearing strata has been established by drilling in the same stratigraphic level as at Sumecani. The field can be exploited as has been proven experimentally, new exploitation wells are being drilled, and exploratory wells also to determine the boundaries of the field. The quality of oil is not the same as at Sumecani, having much more light fractions and much more gas, but also a considerable amount of paraffin.

<u>Klostar (western Kriz structure)</u>

So far, the Kriz structure has been opened for production in the northwestern part (Sumecani) and southeastern part (Bunjani). In the extreme northwestern part of the structure near Ivanic Kloster,

a well was drilled as early as 1905 on the site where, according to old data, there had been gas eruptions.

Taking into consideration these phenomena, and on the basis of the results obtained at Bunjani, a well was drilled at Klostar this year (1952) with positive results. In the rest of the structure oil horizons are situated in the Miocene. Here, however, the presence of oil has been estab'ished in the Abichi deposits which are more fully developed, and have good collectors. Miocene has not yet been explored in this area because rigs with bigger capacity will be needed.

Mramor Brdo

The field was put in operation in 1949. 21 wells have been drilled to date, of which 7 were negative. The other 14 wells are either under exploitation or are being prepared for production. All the wells produce eruptively.

Goilo

The field is almost exhausted. Secondary methods are being applied according to the instructions of Mr. D.B. Taliaferro in his report to the United Nations of May 1952. Of the wells drilled in this field, 53 are positive (43 oil and 10 gas) and 24 negative.

On the southern flank beyond the syncline, folding has been established. Therefore it is possible that a storage of oil occurs which will eventually be reached by deep drilling".

Proposed future exploration as also described by Naftaplin Zagreb are as follows:

1. "Drilling plan for 1953

After the Liberation (1945), the following structures in Croatia were explored by deep drilling: Kriz (Sumecani, Bunjani and Klostar), Mramor Brdo, Janja Lipa, Osekovo, Sedlarica and Dubranec.

The Dubranec structure has been abondoned, being negative.

The positive structures have been put in operation. They are two: Kriz and Mramor Brdo.

Two structures (Sedlarica, Osekovo) are still under exploration, while at one (Lepavina) drilling has been stopped until seismic measuring can be carried out.

At Janja Lipa four wells have been drilled to date, of which two

were positive (gas) and the other two were negative (one of the latter will be further explored). Since larger quantities of gas were established in the two wells, drilling is going on in order to determine the resources and delimit the gas stratum.

The 1953 plan includes the continued drilling of the structures which have been drilled during these years.

In addition we plan to drill the Prozorje (gas), Martinska Ves (oil), and Kozarica (gas) structures.

2. Geologic and Geophysical Work

Geologic surveys will be made in the areas of Zagrebacka Gora, Kalnik, Psunj, Moslovacka Gora, Pozeska Gora and Papuk. The structures which remain to be investigated and explored lie between the above-mentioned mountains or on their slopes.

Generally speaking, only geophysical maps are available for the above structures. The structures are seen as folds or monocline folds. Some of them lean against older massives. It is possible that such structures are closed, if the flank influences of old massives are excluded.

In Slavonia geophysical measurements have been planned (Brzaja-Topolovica-Grubisno Polje-Djakovo-Levanjska-Varos-Imrijevci-Brasevci-Djakovo) with partial completion of gravimetry as well as geologic mapping. The structures having been treated geologically and geophysically will be prepared for deep exploration drilling. These will be carried out on the basis of geophysical work, because geologic mapping is unfeasible in that terrain. From the geophysical point of view these structures are adequately shaped and are of a closed type.

Dalmatia is being surveyed geologically, following which extensive geophysical observation should be carried out, the extent of which will depend upon the results of the geologic work.

Many structures in Croatia thus remain to be explored. The main tasks are as follows:

1. Opening and exploring of new oil deposits.

2. Extending of oil deposits already under exploitation.

3. Exploring of gas deposits to determine whether they also contain oil".

c. Slovenia - Part of the Petisovci structure near Lendava has been explored by drilling, and part by geological, geophysical, and other surface methods. Reference is made to the table in section 4e below and to Appendix 8 for a view of the explorations which have

been made in Slovenia and an indication of the work yet to be done.

4. Known reserves of oil and gas in Yugoslavia

a. Method of computing reserves

Following is a statement, supplied by Nafta Lendava with regard to the method used in Yugoslavia for computing reserves:

"In calculating oil reserves, we use this equation:

V = S.h. gamma. p. alpha

where

S = r^2 pi if r = 100 m - drainage radius

h = thickness of the stratum

gamma = specific gravity of oil (.83)

p = porosity coefficient (.1)

alpha = oil saturation coefficient (.6)

By A-1-a reserves we understand the reserves from the wells which are actually in operation in an area where the strata have already been drilled. These reserves are attained by calculation.

A-1-b reserves represent reserves in the strata of wells which have already been drilled but not yet explored and are believed to be oil-bearing.

A-2 reserves are those which exist between the positive wells.

B reserves are probable reserves which are believed to exist in the vicinity of the positive wells.

C-1 reserves are those which cannot yet be considered as industrial reserves although there are signs of their existence.

C-2 reserves are those established by geologic methods.

Gas reserves may be calculated with the approximate formula:

V = S.h.p.P

where

S = r^2 pi where r = drainage radius

h = thickness of the stratum

p = porosity

P = initial pressure

The calculation is made in this way since we have no instruments for measuring the subsurface pressure, temperature, and other factors which are necessary for more exact calculations of the reserves".

The practical problems involved in the use of this classification, and indeed the classification itself, are matters of continuing interest and discussion. The need for more precise and uniform measurements of quantities and qualities is generally recognized.

b. Total reserves in Yugoslavia

Following is a tabular summary of known oil reserves based on data supplied by the several oil and gas enterprises:

Oil Reserves in Yugoslavia
as of December 1952
(Millions of metric tons)

	A	B and C	Total
Serbia	-	-	-
Croatia	1.0	13.2	14.2
Slovenia	2.6	35.7	38.3
Total	3.6	48.9	52.5

Gas reserves can be summarized as follows:

Gas Reserves in Yugoslavia
as of December 1952
(Millions of cubic meters)

	A	B and C	Total
Serbia 1/	1,600	15,000	16,600
Croatia 2/	265	5,100	5,365
Slovenia	1,318	8,666	9,984
Total	3,183	28,766	31,949

1/ Velika Greda and Jarmenovci
2/ Janja Lipa and Gojlo

The above reserves are all located in the northern plains of Yugoslavia bordering on the Panonian Basin. The inter-Dinaric zone comprising the Vrbas, Kreka, western Morava and Aleksinac areas has not been sufficiently explored to allow any sound estimates to be made. This is also true of the coastal area of Montenegro and Dalmatia.

c. Serbia - Nafta Zrenjanin states that it has not computed oil reserves because the three wells which were drilled have not been completed owing to lack of equipment. Oil strata not yet reached are believed to be 30 to 100 meters thick.

The gas reserves have been computed according to the formula and based on data obtained by deep drilling. The figures shown above do not include the Becej field or other areas believed to be rich in gas but not yet drilled.

d. Croatia - The following detail has been supplied by Naftaplin:

Oil Reserves in Croatia
(Millions of metric tons)

	A-1	A-2	C-1	C-2	Total
Sumecani	.546	-	-	-	.546
Bunjani	.019	.165	.700	-	.884
Klostar	-	-	1.000	-	1.000
Mramor Brdo	.292	-	1.500	-	1.792
Other structures	-	-	-	10.000	10,000
Total oil	.857	.165	3.200	10.000	14.222

Gas reserves in Croatia
(Millions of cubic meters)

	A-1	C-1	C-2	Total
Gojlo	105	-	-	105
Janja Lipa	160	600	-	760
Other structures*	-	-	4,500	4,500
Total gas	265	600	4,500	5,365

*Explored by geophysical methods in Podravina, near Moslovacka Gora, and in Slovenia.

e. Slovenia - The following details have been supplied by Nafta Lendava:

Oil and Gas Reserves of Slovenia

Petisovci formation	Oil (millions of metric tons)	Captive gas* (millions of cubic meters)
A-1-a reserves	1.138	250.360
a-1-b	0.327	71.940
A-2	1.100	242.000
Total A reserves	2.565	564.300

* Captive gas is calculated on the basis that 1 ton of oil contains 220 meters of gas.

B	0.390	85.800
C-1	2.815	619.300
C-2	2.815	619.300
Total B and C	6.020	1,324.400
Total A,B and C	8.585	1,888.700

Lovasi Ratka series in Petisovci formation

Lovasi - A reserves	-	753.600
Ratka - C	-	753.600
Total -	-	1,507.200
Dolina (probably C-1) -		50.000

Other structures - C-1 reserves

Murski Gozd	0.220	48.400
Dolina	0.060	13.200
Lendavske Gorice	1.200	264.000
Kog	4.220	932.800
Selnica-Peklenica	24.000	5.280.000
Total other structures	29.720	6.538.400

Total all structures

A (Lovasi)	-	753,600
A-1-a	1.138	250.360
A-1-b	0.327	71.940
A-2	1.100	242.000
Total A	2.565	1,317.900
B	0.390	85.800
C-1	32.535	7,961.300
C-2	2.815	619.300
Total B and C	35.740	8,666.400
TOTAL all reserves	38.305	9,984.300

5. Production:

Production of crude oil in Yugoslavia has levelled off at about 150,000 tons a year, having reached this volume in 1951. Production at the major fields is currently running about as follows:

Lendava	50,000	tons	per	year
Sumecani	69,000	"	"	"
Mramor Brdo	22,000	"	"	"
Gojla	10,000	"	"	"

The following table shows the trends since the war. As stated above, the pre-war production was negligible.

Production of crude oil in Yugoslavia
(in metric tons)

	Total Yugoslavia	Croatia	Slovenia
1939	1,122 1/	798	-
1946	28,835	22,335	6,500
1947	33,245	25,211	8,034
1948	36,498	25,187	11,311
1949	63,240	37,184	26,056
1950	111,287	53,898	57,389
1951	155,626	80,571	75,055
1952	151,538	101,888	49,650

1/ Including 324 tons produced in Bosnia and Hercegovina from wells that are no longer in production.

Source: Indeks (Statistical Bulletin), Federal Statistical Office. 1952 data from Naftaplin Zagreb, and Nafta Lendava.

Inasmuch as production falls short of domestic needs, the problem is to increase output through secondary recovery methods, by bringing wells into production which are drilled but lack pipe or tubing, and by drilling new wells.

As to natural gas, statistics seem to be lacking on the small quantities which have been produced for commercial use.

Turning now to brief accounts of production in each of the three oil-producing republics:

Serbia: No oil has been produced as yet. Nafta Zrenjanin states that aside from the lack of equipment it has the problem of a large gas factor and high paraffin content. A start was made in production of gas for local use at Velika Greda and for shipment in pressure containers.

Croatia: Two thirds of the total Yugoslavia production is from Croatian wells. Following is the trend in each of the Croatian producing areas:

Oil production in Croatia

	Gojlo Tons	No. of wells	Sumecani Tons	No. of wells	Mramor Brdo Tons	No. of wells	Total
1941	2,158						2,158
1942	9,666						9,666
1943	21,460						21,460
1944	22,481						22,481
1945	25,866						25,866
1946	22,295						22,295
1947	25,211						25,211
1948	25,186						25,186
1949	22,202		6,255	10	3,725	1	37,183
1950	23,657		22,717	20	6,580	2	52,955
1951	17,057	31	50,948	44	7,742	3	75,747
1952	10,525	18	69,417	55	21,947	7	101,888

Source: Naftaplin, Zagreb.
Note the discrepancy between the total for Croatia as shown here and in the preceding table. Naftaplin Zagreb states that the table above is correct and should supersede the figures shown in the preceding table.

The Gojlo field is on the decline. Only 18 wells are still in operation out of the 77 which were drilled and the 53 which were put in operation. Secondary methods are difficult to apply because of the physical properties of the oil-bearing strata.

The Mramor Brdo field was put into production erruptively in 1949. Fifteen wells have been drilled, of which six were negative and seven are now in production. A de-gasolinizing plant is being built which will permit the re-cycling of the dry gas back into the oil strata.

At Sumecani only the central part of the field has as yet been brought into production with the drilling of some 84 wells most of which are producing.

Slovenia: Nafta Lendava explains the drop in production as due to two factors: (1) secondary recovery methods have not been applied, and (2) pressure is falling with the continued discharge of gas into the atmosphere.

6. Consumption

The present level of consumption is about 500,000 tons a year. This is comparatively low for a nation of 16 million people and may be expected to increase substantially with the mechanization of agriculture and the growth of industry.

Refineries with a capacity of about 500,000 tons a year, located at Rijeka, Brod and Sisak, will be expanded to about 800,000 tons a year by 1955. The Rijeka refinery operates only on imported crudes, but Brod and Sisak can handle either domestic or imported crudes. The Sisak expansion will utilize residual paraffinic crude oils which must now be disposed of as bunker fuels. Additions to the Rijeka refinery will make it possible to produce some lubricants now imported. At the present time it is necessary to import high test gasoline, lubricants, and some waxes because of the limitations of refineries.

Natural gas from the Gojlo field has been utilized in small quantities at Kutina for burning chalk, manufacturing lamp-black, and shipment in pressure containers for illumination of railway cars and use as a motor fuel. Here also, as at Lendava and Velika Greda, gas is consumed in the near-by villages. There has been considerable study of gas transportation by pipeline from (1) Lendava to Stirnisce and Maribor. (2) from Mramor Brdo to Sisak and Zagreb, and from Velika Creda to Belgrade, but nothing definite has yet come of the proposals.

7. Program for completion of the inventory of oil and gas

As has become apparent from the above account, only a small part of Yugoslavia has yet been explored for oil and gas. In the view of Yugoslav scientists and petroleum engineers there are favorable indications for the existence of petroleum in other parts of the country. The area over which it is proposed to extend the explorations has been shown in Figure 13. It has also been described in the section above on the geology of fossil fuels, and in the statements of the work being carried on by the several oil and gas enterprises.

With these views the writer is neither in a position to agree or to disagree because he is not qualified in the matter of oil exploration. It is hoped however, that the information here presented will provide a helpful perspective for others more competent.

In summary, the view is generally held in Yugoslavia that explorations should be continued somewhat as follows:

a. Continued exploration of the northern plains areas bordering on the Panonian Basin, to complete and round out the work started by the Germans during the war.

b. Extension of the geophysical explorations, followed by structural drilling as appropriate, 1) to other marine Tertiary basins in the south side of the valley of the Sava toward the foothills of the Dinaric mountains, and 2) to the tertiary belt which parallels the Sava and the Dinaric range from the lower Vrbas through the Kreka coalfields to the Aleksinac coalfields in the Morava River valley.

c. Exploration of the Dinaric range, and the other structures along the Adriatic coast, by geologic methods followed by deep drilling and by geophysical work in local areas. Here the mountainous character of the terrain reduces greatly the usefulness of geophysical methods.

The fundamental processes employed in petroleum exploration continue, of course, to be geology, the more modern geophysical techniques, and structural drilling. The latter is accompanied by laboratory analysis of drill cores, and measurements of pressure, porosity, and other underground conditions. Reserves can then be computed according to accepted formulas and classified according to the classification in general use. Good cadastral and topographic surveys are necessary for the control of stratigraphic work. Economic appraisal should constantly be made of probable production costs as compared with the probable value of reserves.

Whatever program of exploration is decided upon should of course be selected with a view toward obtaining the maximum results from the application of the limited manpower and technical equipment available. Because the work of exploration and production is divided between a number of enterprises and scientific bodies in the several republics, measures should continue to be taken to prevent the scattering of work over too large an area, to concentrate efforts on a desired number of top-grade projects or areas, and to establish priorities for explorations on the basis of over-all national considerations.

Turning now briefly to the means at hand for carrying out a program of exploration, it may first be observed that although much has been accomplished with the equipment and the trained men available, the lack of facilities has often made it difficult or impossible to achieve satisfactory results. This observation is applicable alike to the geophysical, drilling, and related laboratory and other technical work.

Nothing can be ventured here by way of comment on the problems of geological research or the means that should be provided to facilitate this basic work. Suffice it to say that the necessity for continued progress would seem to be unquestioned. Geology provides the basic knowledge of the physical structures from which the geophysical and drilling operations can proceed.

As to geophysical techniques, they are comparatively new and constantly being improved. They have of course come to be an essential tool without which exploration is both costly and uncertain. Nevertheless so far as petroleum explorations are concerned, the geophysical facilities are inadequate to do the work which is expected of them. Instruments and equipment are for the most part old and many are either partially or wholly obsolete. They are not capable of the volume of work or the precision which is desirable. Seismic apparatus, which is particularly necessary for the deeper explorations, is almost wholly if not completely lacking. The statement provided by the Institute for Geophysical Research at Zagreb contained in Appendix 9 is illustrative of this situation.

It must be emphasized that both equipment and trained operators are needed. Equipment without the operators is only partially usable.

Drilling equipment is also somewhat lacking, particularly the deep drilling rigs. Owing to a shortage of foreign exchange much of the equipment is either prewar or rebuilt from war salvage.

Small field laboratories for the analysis of cores and other work may be needed in greater numbers and with more complete equipment than at present. Whether the most appropriate division of work has been arranged as between field laboratories and the central research laboratories was not determined.

It may also be mentioned that the necessary instruments for underground measurements are often lacking, thus making it difficult or impossible to achieve the required degree of accuracy in the computation of reserves.

We have called attention frequently to the lack of trained and experienced technicians and engineers. Although much experience has been gained during the postwar years, it must be kept in mind that the petroleum industry is new in Yugoslavia and that most engineers and other oil field workers were thrown into the work without previous experience. They were left to themselves when the Russians left in 1948 and have since proceeded as best they could. In fact, few Yugoslav engineers have seen an oil well except those which they have drilled in their own country. Their obvious need is for the maximum possible contact with oil people in other countries.

As to economic analysis of petroleum explorations and production it is handicapped by the unstable price levels and price relations

generally prevailing and the absence of accepted principles for the determination of costs and economic feasibility. Until economic analyses can be made, the engineers operate somewhat blindly in laying out their exploration programs and appraising the worth of the resources discovered.

8. Foreign Assistance:

The above brief review of the proposed plan of explorations and the facilities available to carry it out should be suggestive of the ways in which foreign aid could be applied to advantage. The informal request made by one of the oil enterprises for foreign technical assistance may also be suggestive. This request included the following:

1. Foreign travel and training for Yugoslav engineers and technicians in each of the following subjects:

   Oil geology
   Geophysics
   Deep drilling
   Exploration, secondary recovery, and production
   Compressor stations and pipelines.

2. Seismic equipment for the geophysical institute.

3. Instruments and equipment for an oil laboratory and for underground measurements.

4. Drilling rings and tools for both deep and shallow wells.

5. Foreign experts to come to Yugoslavia in each subject listed in item (1) above.

6. Literature.

This statement would be more or less closely repeated by other oil and gas enterprises.

Although so specific recommendations for UN Technical Assistance will be made here it is urged that in view of the obvious benefit which would accrue to Yugoslav engineers and technicians from experience and contact with their counterparts in other lands, the most favorable reception should be given to any requests which may be made along the general lines mentioned above.

Several suggestions have been made that the first step would be to send Yugoslav engineers and technicians to petroleum centres in other countries. As regards foreign experts coming to Yugoslavia the first step might be to petroleum engineers who could provide assistance up to the limits of their abilities and who might propose the more specialized assistance which should follow.

Through other channels a recommendation is being made that UN supply a selected list of professional and trade literature for which the need appears to be so obvious as to merit immediate attention.

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Oil and gas enterprises

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Nafta Lendava	(Slovenia)
Naftagas Zrenjanin	(Serbia)
Nafta Tuzla	(Bosnia)
Nafta Ulcinj	(Montenegro)

Oil and gas institutes

Institut za naftu, Zagreb
Geological and geophysical institutes of the republics of Serbia, Croatia, Slovenia, and Bosnia
Geological institutes of the Academies of Science in Ljubljana, Zagreb and Belgrade.

Publications

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Casopis "Nafta" (Magazine "Gas")
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List of oil scientists and engineers

Prof. S. Lazic, Zagreb
Prof. Ozegovic, Zagreb
Prof. Mihajlovic, Beograd
Prof. Pavlovic, Beograd
Prof. Slokan, Ljubljana
Ing. Vuskovic, Zagreb
Ing. Paradjanin, Zrenjanin
Ing. Cerovac, Dol. Lendava
Ing. Lucic, Ulcinj
Ing. Kornelije Mirkov, Beograd
Ing. Dj. Dimitrijevic, Beograd

D. Coal

1. Introduction

Solid fuels are a major energy resources in Yugoslavia, although less important as compared with hydro than in the major industrial countries of Europe.

Lignite is the most important of the solid fuels. The full extent of the lignite resources is only now becoming known. Recent discoveries in the Kosova Basin, for example, have led to the doubling of the known reserves. Equally important is the fact that the large lignite beds are well located with relation to the centers of population and to transportation, and seams are sufficiently shallow to lend themselves to economical exploitation.

Solid fuels have not as yet, however, played a correspondingly significant part in Yugoslav energy consumption. New demands are coming, it may be noted, from (1) the replacement of fuelwood, which must be conserved and diverted to higher uses, and (2) the expansion in total energy use which accompanies the countries industrialization. At the same time, the advancing technology promises to make solid fuels, and especially lignite, a source of raw material for agricultural and industrial chemicals. Lignites are not being utilized at present in proportion to their reserves as compared with brown coal and hard coal. Official policy is to bring the use of lignites into better proportion with their relative abundance.

The purpose of this chapter is to provide a general perspective on the solid fuel resources of Yugoslavia, particularly with respect to their extent and quality, with a view toward facilitating the determination of the further steps that should be taken to complete and improve the inventory.

Principal sources of data for solid fuels have been the Economic Council of the national government, Professor Samec of the Institute for Fuels of the Academy of Science in Ljubljana, Ing., Boza Popovic of the Institute for Research in Coal in Belgrade, and Vjekoslav Mikincic, Director of the Federal Geologic Institute at Belgrade.

The coal industry was administered several years ago by coal mining directions established in each republic and in the national government. Production is now handled by a mining enterprise established in each republic, with local management for the individual mines. The governments of the republics have offices for general planning of coal production and for geologic and laboratory work needed. The larger mining enterprises each have their own geologist, surveying staff, drilling rigs for exploration, and other major facilities, whereas the smaller mines frequently resort to the laboratory and other facilities afforded by the mining institutes. In addition, there are institutes for coal research in the Academies of Science of Serbia and Slovenia where basic scientific research is conducted in the utilization of solid fuels.

2. Methods for determination of reserves

(a) Explorations. Geology, mining, drilling, and more recently geophysics, are the tools of exploration for coal. These methods are accompanied by laboratory analyses to determine the physical and chemical properties.

A brief review of the geologic investigations has been given above in the section on the geology of the fossil fuels. Supplementing this review, it may be said that at the end of the 19th century and during the early years of the 20th, Katzer, Beyschlag, Krusch, Waagen, and other German and Austrian geologists investigated the coals in the areas which were then part of Austria-Hungary. Between the two World Wars the Yugoslav geologists and mining people continued the investigations, particularly in Serbia. At present new investigations are being performed for the most part by the geologists attached to the individual coal mines. They send detailed geological maps to their respective republics and federal geological institutions. Their exploratory equipment consists, however, of only a few drilling rigs. Geophysical methods are now being applied to a limited extent.

A summary of the geology of the Yugoslav coal deposits is provided in "Geology for Miners" by B. Milovanovic, Belgrade, 1950. Published works are few, although special studies are available in limited quantities through the various mining and scientific institutes.

The lignite basins of Kreka, Velenje, Kolubara and Kostolac have been rather well explored, while the lignites of Kosovo, Plevlje (in Montenegro), Oslonej (in Macedonia) and some sites in Bosnia have not yet been adequately investigated.

As geologist Mikinoic of the Federal Geological Institute has stated, although geologic investigations were started in Yugoslavia at a time when the science was already well-developed elsewhere, they were not carried out systematically until the formation of the Republic. Only after the end of World War II were organized and systematic geologic investigations undertaken.

(b) Classification of reserves. Until World War II, Yugoslavia used the so-called English system of classification. It may be generally said that except for the larger and more profitable coal properties, detailed explorations were very limited, and in any event results were not published or reported to government bodies. The quality of the investigations and of the data on coal reserves was thus very uneven. Good data were available on some deposits but not on others.

With the nationalization of mines in 1945 the first necessity was to bring all available data together on a uniform basis for all mines. The English classification was thought to be too subjective and otherwise unsuitable for a state-directed economy. The Russian classification was adopted and all data were reorganized on this new basis. Under the direction of teams of engineers who travelled from mine to mine, the available data were re-worked into what is believed to be the most usable inventory yet available based on this new inventory.

Current thinking in Yugoslavia with regard to classification is reflected in the statements contained in Appendixes and referred to above. The Russian method has not proven satisfactory. Efforts are being made to find a system which is more objective than the old English classification while not so rigid and costly to apply as the Russian. An effort is also being made to introduce elements into the classification which provide some guidance to management as to the most desirable parts of the deposits to work from a cost view point. The new system must also be sufficiently simple that it can be applied by smaller mines.

Thus the task of improving and codifying the known data on solid fuels continues. It is obvious that as and when agreement is reached on new standards of exploration and classification, the data on each deposit must necessarily be reviewed to bring them into conformity with the new classification and to reveal the more serious deficiencies.

(c) Quality of coal. The basic current reference work on the quality of Yugoslav coals was compiled in the years since World War II and published in 1951. Although the particular purpose for which it was prepared has now passed, namely the establishment of a uniform price for coal of each particular grade, it is of continuing usefulness as a reference on the properties of the coal of each mine or deposit.

The necessity for analysis of the quality of its coals has always been recognized by Yugoslav scientists. Their attention is now being directed particularly at the low-grade lignites whose abundance has already been referred to, many of which can be produced cheaply by open-cast methods. Recent experience has demonstrated that improved lignites with the same calorific value can be produced more cheaply than the brown coal that has been the principal solid fuel of the country.

Accordingly, the lignite of the Kolubara Basin has been thoroughly explored both for quantity and quality, while the other large lignite basins of Kosovo, Plevlje, and others remain to be explored. The investigations include the suitability of the lignites for mining and the various methods of washing, drying, coking or other forms of beneficiation. Following are the main properties for which the lignites are tested:

(a) Property of washing for the removal of dirt;
(b) Heat content;
(c) Drying properties; strength of the dried coal;
(d) Content and the quality of volatiles;
(e) Sulphur content and possibility of removing it;
(f) Coking properties;
(g) Gasification properties;
(h) Chemical analysis;
(i) Moisture content.

Because the lignites within the same deposit have such different properties at various points in the deposit, it is recognized that the best site for

exploitation cannot be determined until extensive tests have been made of the whole deposit. That is the stage at which the Kosovo Basin now is.

The tests which require precise methods and extensive laboratory equipment are now made at the central laboratory in Belgrade of Ing. Bozo Popovic and in Ljubljana at the institute directed by Professor Dr. M. Samec. Elementary testing of samples and cores is done in small field laboratories at the sites of exploration.

Ing. Popovic is currently participating in the work of the United Nations commission in Geneva on rules and standards for the classification of low-grade fuels for quality.

3. Reserves as now known

(a) Summary view. The following table summarizes the solid fuel reserves in Yugoslavia as now known:

TABLE I

COAL RESERVES OF YUGOSLAVIA

(millions of metric tons)

	A	B	C	Total
Hard Coal	6.1	6.6	38.0	50.7
Brown Coal	82.5	152.3	1,547.1	1,781.9
Lignite	81.2	571.1	18,706.0	19,358.3
Total	169.8	730.0	20,291.1	21,190.9

The location of the coal fields is shown in figure 14.

Two aspects are apparent: First, the reserves of mineral coal and brown coal are comparatively small. Second, only a small proportion of the reserves have been fully explored. Thus the A and the B reserves are less than 5% of the total known reserves.

Compared with other European countries, Yugoslav hard coal deposits are insignificant, totalling as they do only some 50 million tons out of a total for Europe of 643 billion tons. In brown coal and lignite, however, Yugoslavia has about 20 billion tons as compared with a total of just under 100 billion tons for Europe as a whole. In fact, Yugoslavia's lignite deposits are larger than any other country in Europe except East Germany, comparing with 18 billion tons in West Germany and 12 billion tons in Czechoslovakia (source: ECE Power Transfers p.79).

(b) Hard coal. Hard coals are found mainly in Istria and eastern Serbia. These coals have a thermal value of about 6500 kcal/kg. The Istrian coals have been utilized mainly in Italy. Although the coal is high in sulphur content the Italian plants and locomotives are adopted to its use.

The principal hard coal deposits are shown in the following table:

TABLE II

RESERVES OF HARD COAL

(in millions of tons)

	A	B	C	Total
Istria Basin (Rasa)	4.8	5.4	27.8	38.0
Eastern Serbia	.3	.2	6.8	7.3
Ibar River (Serbia)	1.0	.9	.5	2.4
Majevica (Bosnia)	-	.050	3.0	3.0
Total	6.1	6.5	38.1	50.7

Source: National Economic Council

(c) Brown coal. The principal deposits of brown coal are found in the Sava River Basin of Slovenia, the Bosna River Basin of Bosnia, and in the Morava Valley of Serbia. They have a thermal value of from 3500 to 5000 kcal/kg. Brown coal belongs exclusively to tertiary formations, the deposits in Slovenia being badly faulted and folded, while the structures in Bosnia are more simple. The depth of the deposits is moderate, and there is some possibility of open-cast operations, as at Banovici in Bosnia and Trbovlje in Slovenia.

Table 3 lists the principal known brown coal deposits.

(d) Lignite. These low-grade fossil fuels, with a calorific value of from 200 to 3500 kcal/kg., are foundin three large deposits, namely, Kosovo in southern Serbia, Kreka in Bosnia, and Kolubara in northern Serbia, with a fourth deposit of considerable size and importance at Velenje in Slovenia. Table lists the main known deposits.

Lignite is found in the upper tertiary as at Kreka, or the lower Miocene, as at Velenje, Kolubara, Kostolac, and Kosovo. The deposits are comparatively thick (from ten to one hundred meters) and unbroken. Lying close to the surface as many of them do, the lignites offer possibilities for economical open-cast production.

TABLE 31

RESERVES OF BROWN COAL

(in millions of metric tons)

	A	B	C	Total
Aleksinac Basin	.4	.2	26.1	26.7
Senj - Resava	2.5	.5	19.7	22.7
Despotovac	.5	.4	16.5	17.4
Janko's Gorge	-	5.8	34.3	40.1
Soko	.3	4.7	15.8	20.8
Mlava Basin	.7	15.3	140.4	156.4
Vrdnik Basin	.1	3.1	3.0	6.2
Jelasnica Basin	.3	.2	3.4	3.9
Bogovina Arandjelovac	.1	.2	3.0	3.3
Banovici Basin	42.6	27.4	268.0	338.0
Central Bosnian Basin (Zenica, Kakanj, Breza)	13.8	40.6	645.6	700.0
Livno - Duvno	.8	21.7	-	22.5
Ugljevica Basin	1.4	5.8	18.8	26.0
Miljevina, Mostar Suhaca, Banja Luka	8.0	9.6	13.0	30.6
Zagorje	1.4	2.0	96.6	100.0
Trbovlje - Hrastnik	4.8	2.6	20.8	28.2
Zabukovca, Kanjizarica Kocevje, Liboje, Senovo St. Janez, Lasko	4.6	11.6	13.0	29.2
Golubovac - Siveric	.2	.6	9.1	9.9
Other	-	-	200.0	200.0
Total	82.5	152.3	1,547.1	1,781.9

Source: National Economic Council

TABLE IV

RESERVES OF LIGNITE

(in millions of metric tons)

	A	B	C	Total
Kostolac Basin	2.7	11.0	300.0	313.7
Kolubara Basin	55.0	-	1,445.0	1,500.0
Kosovo Basin	2.7	3.0	12,194.3	12,200.0
Lubnica, Petrovac and Leskovac Basins	.5	.2	.8	1.5
Kreka Basin	12.4	84.1	3,903.5	4,000.0
Konjscina, Ratkovica Ivanec, Mur. Srediste Bolgi Basins	2.7	9.9	262.9	275.5
Velenje Basin	4.9	450.0	295.1	750.0
Kicevo Basin (Oslomej)	.2	7.5	120.0	127.7
Plevlje Basin	-	-	156.8	156.8
Zivojno, Katlanovo Nerezi, Svilare Basins	.1	5.4	27.6	33.1
Total	81.2	571.1	18,706.0	19,358.3

Source: National Economic Council

4. Production of solid fuels

Pre-war requirements were met by a domestic production of some 7 million tons, together with the importation of ½ million tons of hard coal. Present domestic production is about 12 million tons and imports are negligible. Needs by 1955 or 1956 are estimated at 18 million tons, to meet which domestic capacity of 20.2 million tons is planned, with an expected capacity utilization factor of 90%.

As may be seen from Tables 5 and 6, the production of brown coal and lignite has doubled as compared with pre-war production.

Bosnia, with its brown coal and lignite mines is the largest producer of solid fuels, followed by Serbia and Slovenia.

Following the second war, Yugoslavia made a determined effort to rationalize its coal mines and expand production. Old mines were put back into production, capacity was increased, and new mines were opened. The limiting factors have been the availability of labor and machinery. As will be noticed from the tables, production has flattened out at 12 to 13 million tons since 1949. As has been mentioned, further expansion to about 20 million tons is scheduled by 1956.

Although the recent expansion has occurred in both brown coal and lignite, it is expected that lignite will henceforth show the largest and the most persistent growth. This is because the lignite deposits are larger and lend themselves to the more economical and highly mechanized open-cast methods. With the opening of more lignite deposits the marginal brown coal mines may be abandoned. It must be emphasized, however, that exploitation of lignite hinges on the success of methods for its beneficiation, including washing and drying to make a good solid fuel for homes and industry, production of coke, and other processes such as gasification, distillation and hydrogenation.

5. Consumption

(a) By principal consuming groups. Following is a tabular summary of the use of solid fuels by principal consuming groups in 1950:

	(thousands of metric tons)
Mining and industry	5640
Transport	3360
Power generation	1800
Household consumption	1120
Miscellaneous	760
Export	
Total	12680

Source: Data supplied by Yugoslav government to International Bank.

TABLE V

PRODUCTION OF SOLID FUELS BY REPUBLICS

(thousands of metric tons)

Year	Total	Serbia	Croatia	Slovenia	Bosnia & Hercegovina	Macedonia	Monte Negro
1939	6,973	1,693	1,663	1,852	1,765	-	-
1946	6,804	1,693	1,168	2,044	1,899	-	-
1947	9,291	2,434	1,654	2,436	2,767	-	-
1948	10,724	2,999	1,757	2,562	3,406	-	-
1949	11,107	3,230	2,151	2,706	3,980	25	15
1950	12,866	3,441	2,056	2,830	4,500	21	18
1951	12,043	2,999	1,817	2,652	4,525	35	15
1952	12,098	2,970	1,955	2,644	4,496	16	17

Source: Index

TABLE VI

COAL PRODUCTION IN YUGOSLAVIA

(thousands of tons)

Year	Total	Hard Coal	Brown Coal	Lignite
1939	6,973	1,351	4,312	1,310
1946	6,804	757	3,823	2,224
1947	9,291	1,062	5,325	2,904
1948	10,724	973	6,331	3,420
1949	12,107	1,275	6,682	4,151
1950	12,866	1,154	7,204	4,508
1951	12,042	992	6,916	4,134
1952	12,098	1,011	6,842	4,245

Source: Index

(b) Per capita consumption. Inasmuch as the bulk of the above solid fuels are the low-grade lignites and brown coals, the thermal value is even less than the total would indicate. Consumption compared with other European countries is as follows for the year 1949:

Availability of unprocessed solid fuels per capita, 1949

(equivalent metric ton)

United Kingdom..................	4.08
Germany........................	2.32
Poland	1.92
Belgium, Czechoslovakia France and Netherlands..........	2.00
Rest of Europe..................	.42
Europe average	1.63
Yugoslavia	.30

Source: ECE, Selected European Energy Statistics, Geneva, May 1951. Yugoslav data based on Table 6 of this report with the use of a factor of .33 to convert brown coal and lignite to hard coal equivalent. This factor was employed by ECE for the Southern European countries. Use of a more appropriate factor for Yugoslavia does not change the result materially.

The low use of fuels in Yugoslavia may be attributed both to the lack of industrialization and to the comparatively low productivity of labor in the coal mines.

(c) Trends. Off-setting the growing energy requirements in Yugoslavia is the trend toward greater efficiency of utilization. Thus the present stoves used for spaceheating in homes and shops are not well adapted to the use of dried lignite. This is also true of locomotive boilers. The use of coal in industry is not rational at present because of obsolete boilers, overloading of equipment and deterioration of the quality of fuel. By modernization and adaptation of furnaces and boilers to available types of coal (particularly the use of automatic stokers for coal fines) efficiency of utilization can be greatly increased.

(d) Exports and imports. As to foreign sources for solid fuels, although Yugoslavia is now importing some bituminous coal and industrial coke, there are no nearby sources for solid fuels which offer an economical and dependable supply. Most coal producing countries in Western Europe are having difficulty meeting their requirements, and more distant sources are no more promising.

Exports of solid fuels from Yugoslavia, on the other hand seem more likely to expand in some degree. Brown coal can possibly be marketed in Austria and Western Germany, Istrian hard coals in Italy, and improved lignites in Greece and the Middle East.

(e) Adequacy of reserves for future needs. No attempt will be made here to estimate the probable future magnitude of coal consumption. Suffice it to point out that the increase of annual consumption to the European average of 1.63 tons of hard coal equivalent per capita would involve a five-fold growth of consumption to about 60 million tons per year. Measured against this standard, the projected increase of production to about 20 million tons per year by 1956 seems modest.

How adequate are Yugoslavia's solid fuel reserves? By way of illustration the following figures may be set down:

Known reserves of solid fuels......	20,000 million tons
Possible realization factor........	70%
Net realization solid fuels.........	14,000 million tons
Annual requirements	
As fuels, say......................	60
For ½ million tons per year of liquid fuels at 10:1 ratio......	5
Other chemical uses................	5
	70 million tons

Reserves on this basis are thus equal to 200 years' requirements.

For the above figures can be substituted whatever assumptions or data one cares to use. Conservation-minded individuals can find in them the grounds for urging the most rational utilisation of the nation's energy resources. Others with a more sanguine turn of mind may be inclined to let matters take their course. Resolution of these opposite inclinations on the basis of a careful determination of all energy reserves, probable national requirements, and rational utilization, is needed to arrive at a policy and program for energy resource exploitation and conservation.

6. Processing of lignite

The processing of hard coal or brown coal poses no peculiar problem to Yugoslavia. As regards lignites, however, the improvement of their calorific content is an essential step in their utilization. Yugoslavia has therefore done much work in adapting known processes to its own conditions and in pioneering in the techniques of lignite processing.

In their native state, the lignites are so low in calorific value and have such other properties that they are not economically usable. Thus owing to their high moisture content and the large proportion of inert material, the thermal value may be in the neighbourhood of 2,500 kcal/kg. as compared with perhaps 7,500 kcal/kg. for hard coal. The lignite is not only difficult to burn, but it will not stand the cost of transportation for any appreciable distance. Lignite is also easily fractured in handling and transportation and by exposure to air.

When put into their context of Yugoslav needs and conditions, these properties of lignite pose the following specific problems:

(1) to produce an improved solid fuel for domestic and industrial use;

(2) to produce an industrial coke;

(3) to utilise the fines effectively;

(4) to develop processes for the most effective overall utilization of lignites both for their thermal value and as a raw material.

These problems are in a fair way toward solution, thanks to the work of Yugoslav scientists.

(a) Improved solid fuel. The first step in the improvement of lignite is washing and drying to produce a solid fuel suitable for domestic, industrial and railroad use. Inert matter is removed by washing in heavy medium (water mixed with quartz sand) following which the lignite is dried in steam or hot water under pressure. The product is a fuel of from 20 to 100 mm in size and with a thermal value of 4,000 kcal/kg. (equivalent to about 7,200 Btu/lb.), 13% ash, and 18% moisture, which can be transported and stored without substantial further breakage and which will not again absorb moisture. It is, therefore, suitable for the domestic, industrial and locomotive use for which good fuels are now lacking.

As to the fines, which at the mine-mouth are from 15% to 25% of the tonnage produced, and are increased further by breakage as the lignite is screened, washed and dried, it is believed that the technical problems of their beneficiation and use have likewise been solved. They can, of course, be burned in thermal power plants erected at the site, either in their raw state or after drying to improve their thermal value. This will probably be the first use to which the fines will be put. Thermal plants will be built, for example, at Velenje, Kreka and Kolubara. Thermal production can probably be concentrated in the summer months when hydro production is at its seasonal low. The fines can also be dried for gasification, or washed and dried for coking or for use as an industrial fuel. The washing is done in batteries of cyclone washers, and the drying by floating in hot air or gases.

Washing and drying plants have been built at Kreka, and will also be built at Kolubara.

(b) Manufacture of coke. Lacking a suitable supply of coking coal, Yugoslavia has encouraged its scientists in the pursuit of a method for the carbonization of lignite. Recent studies of the coking of lignite and other native coals which do not coke with established processes have justified the construction of the first plant for the making of coke from a mixture of hard coal, brown coal and lignite. The plant has just been put into operation at Lukavac in the Kreka basin.

Further experiments are being directed to the artificial aging of young lignites to the grade of coal susceptible of coking through the introduction of additional coal tar compounds obtained from the coking process itself. It is confidently expected that an all-lignite coke can be produced on a commercial basis in a one-stage process.

(c) Industrial complex based on lignite. This is not the place to elaborate on the more involved processes for the utilization of lignite. Suffice it to say that Yugoslav scientists believe that their lignites will lend themselves to carbonization and gasification, and through these processes will provide the basis for the manufacture of agricultural and industrial chemicals, starting perhaps with fatty acids, paraffin and nitrogen compounds. The gases with higher calorific value (such as methane, ethane and propane) can be separated for transportation by pipeline from the coal fields to nearby industrial and population centres for use as a fuel or raw material.

The emphasis will, of course, differ at each field depending on the situation with respect to the characteristics of the lignites, the availability of natural gas, higher grade coals, or other fuels, the market requirements for fuels and for raw materials based on the hydrocarbons, and similar factors. Thus, the Velenje lignites are regarded as appropriate for gasification because they are located in a populated and industrialized area. By contrast, the Kolubara lignites are expected to be used for preparation of improved solid fuels, but with the manufacture of limited quantities of gas for use as a raw material and heat source for industries which would be located in the immediate area.

An advancing technology, thus gives every promise of making its lignite deposits the nation's primary source both for fuels and for raw materials for industrial and agricultural chemicals.

7. Program of exploration

Much is known about its coal deposits, there seems to be general agreement that further explorations are needed with respect to the quantities and the qualities of this important energy resource. Undoubtedly many deposits remain to be discovered, and it is certain that known deposits are only partially explored. Hence the government is interested in moving ahead with the improvement and the completion of its inventory of solid fuels as rapidly as conditions will permit. Until more is known, for example, about the lignites in the great Kosovo deposit, it is impossible to select the most likely sites for initial exploitation or to prepare a general plan for the entire bed.

(a) Methodology and classification. As indicated in Appendixes 5 and 6 referred to above, the first step appears to be to review carefully the standards used for investigating and classifying reserves. This would involve agreement not only on the quantitative and qualitative aspects but also on the physical aspects of the deposits so far as they affect the feasibility of production and utilization. The commission proposed at the Energy Resources Conference in February is

presumably at work on this aspect of the problem, proceeding with the consideration of the situation in each republic and then aiming to reach agreement on a unified approach for the country as a whole. The prominent part taken by Ing. Popovic in the deliberations of the UN commission on standards for classifying the quality of fuels is helpful in this connection.

(b) Explorations. Upon the basis of the agreed-upon methodology and standards, the next step would presumably be to undertake a thorough review of known data and the extension of explorations to areas where data is deficient or completely lacking.

Topographic surveying, supported by cadastral surveying, is necessary in a number of areas, such as in the Kosovo basin, to facilitate the correlation of geologic work and for other purposes. Photogrammatic techniques will be employed as a matter of speed and economy to a great extent.

Geologic surveys should be continued in accordance with the general approach discussed above.

Geophysical methods can be used to great advantage in conjunction with other methods. Here again the lack of modern equipment (especially seismic devices) and trained technicians, is a limiting factor.

Drilling and mining continue, of course, to be used for detailed explorations.

(c) Processing of lignites. Because the development of processes for improving the quality of lignites and for converting them into useful fuels and raw materials for industry is the key to the usefulness of these abundant resources, there is every reason for moving ahead as rapidly as possible with the scientific and applied research on which Yugoslav scientists are so well advanced. This would include techniques for washing and drying, coking, gasification and chemical utilization for ammonia, fertilizers, and other products. Upon the results of their work will hinge not only the unlocking of the very considerable lignite reserves, but also the determination of a sound national policy with regard to these and other energy resources, and indeed, industrial development as a whole.

(d) Foreign assistance can undoubtedly be used to an advantage in many aspects including exchanges of views and experiences on the methodology and standards for exploration and classification, methods of exploration, and certain phases of the research in the processing of coal. Here, as in the case of other fossil fuels, the need is for instruments and equipment for geophysical and photogrammatic surveying, including the training of technicians. An opportunity is also desired for Yugoslav chemists to go abroad to acquire laboratory experiences in the washing, drying, and coking of lignites.

It may also be that the government will find it worthwhile to invite a generally competent coal expert to come to Yugoslavia for several months to review the situation and for consultation on the main problems. While he would be expected to extend his attention to all the solid fuels, he would undoubtedly devote himself particularly to the exploration and exploitation of lignites. It is my understanding that the technical assistance program for 1953 includes an expert on coal production. It might be possible to combine in one person the desired qualifications in both production and exploration.

E. Oil Shales

1. Introduction - Although one of its minor energy resources, oil shales continue to attract interest and attention in Yugoslavia because of their possible source for liquid fuels and other coal tar derivatives. Several of the larger deposits were explored before World War II, notably by the French in 1935. During their occupation of Yugoslavia the Germans engaged in exploration under their Prof. Deyschlag.

Subsequently the Yugoslav geologists and scientists have carried their studies further, both with regard to the size of the reserves and to their possible exploitation. The crisis in oil supply created in 1948 by the break with Russia stimulated efforts to extract oil from shale as a domestic source of supply. With the improvement in the situation in 1949 these efforts were relaxed and the company which had been organized for the purpose of exploiting the Serbian shales was dissolved. Nevertheless, exploratory work is being continued on a small scale under the auspices of the Serbian enterprise "Rudnik." As yet, however, there has been no commercial exploitation of oil shales in Yugoslavia.

2. Reserve - The principal known reserves are shown in Figure 13 (map of oil and gas explorations).

Aleksinac in eastern Serbia is the leading deposit, according to present knowledge, with reserves estimated in the neighborhood of several hundred million tons, of which a large part is said to contain more than 14% bitumen.

The second most prominent deposit is near Sinj on the Dalmatian coast for which no reliable estimates are available but whose reserves are variously estimated at from 20 to 200 million tons.

Other deposits are found at Kakanj in the Besna valley and Zlotovo in Macedonia, but no figures are available on the size of these reserves. There are smaller deposits at Vakup-Rankovicevo and Trstenik on the Western Morava, Cicevac in the Morava Valley, and Slovac-Kolubara, all in Serbia.

Along the Dalmatian coast there are quantities of bituminous limestones and shales of the Jurassic or Triassic age which are of such low grade as not to be classified, but which may have economic importance if they can be burned underground.

The Aleksinac shales are described in some detail with report prepared by Ing. Matić, director of undertaking "Rudnik" attached as Appendix 10. They are found in conjunction with brown coal in seams of considerable thickness but in inclined structures that make mining difficult. Accordingly it seems clear that the coal and the shales should be mined together. Explorations have not been sufficiently thorough or comprehensive to permit any reliable calculation of reserves or to provide a basis for exploitation.

A statement by Ing. Petrunić, Zagreb, is attached in Appendix 11.

The Sinj shales are located some 25 miles from the sea in the coastal limestone formations. These deposits have been studied by Prof. Luković of Belgrade and Prof. Margetić of Zagreb. The latter's report published in 1952 is the most useful source of information. Only a small part of the area has been systematically explored. The bed is formed of several parallel deposits which contain thin strata of bituminous shale and which lie at a steep angle and in some sections at a considerable depth.

Tar content ranges up to 30% and is rich in paraffin. The richer shales have a lower melting point than the Aleksinac shales, which adds to the problem of retorting. Sulphur content is high.

Because of their limestone content, the recovery of the tars and gases can be combined with the manufacture of cement. The same rotary kilns used for making cement can probably be used for extracting the tars, the tar-laden gases being exhausted from the upper end of the retort and the clinkers being used for the cement. Experiments conducted during the summer of 1950 at the cement factory at Selin near Split are said to have yielded satisfactory results. According to Dr. Aleksandar Petrunić of Zagreb, the processing of the Sinj shales is economical only conjunction with the production of cement.

Apart from the method of retorting of the Sinj shales, there is still the problem of further exploration to determine the size of the deposits and the percentage and characteristics of the bitumen content.

3. Retorting of oil shales - A pilot plant built in Aleksinac in 1948 achieved an overall efficiency of 80% in the recovery of tars from the Aleksinac shales. This experiment is described in Appendix 10. Tests then were made in a larger plant but an efficiency of only 45% was obtained and the work was stopped. Inasmuch as the Aleksinac shales are similar to those in Colorado (although the Yugoslav tars are richer in the lighter fractions), there has been some effort to exchange information and experience with the Bureau of Mines Laboratory at Rifle.

Distillation of the tars recovered from the shales poses further problems for research. Attention has been given to deparaffing and to the use of a cracking process to recover the lighter fractions. The addition of a cracking plant at the Sisak oil refinery provides facilities for the treatment of the shales tars. As yet Yugoslavia has no hydrogenation plant in operation.

4. Program of exploration and research -

a/ From the above it may be seen that a good start has been made in explorations of the quantity and the quality of oil shales in Yugoslavia. The Aleksinac and Sinj deposits have been given most attention, but not enough is known about them to permit the beginning of exploitation.

Explorations will presumably be continued as man-power and facilities permit. This will involve the use of geological, geophysical, drilling and mining methods as in the case of coal and the same problems of classification of the reserves.

b/ Mining presents some problems, as at Aleksinac and Sinj. Continued attention is being directed toward these problems. Mechanization is being considered at Aleksinac for the simultaneous mining of coal and shale.

c/ As to the retorting of shales, the Yugoslavs have concluded that the "gas combustion" method worked out by the Bureau of Mines at its Rifle Colorado experiment station is the best adapted to their conditions. Assuming that the experience gained at Rifle can be made available to Yugoslavia, the problem remains of adapting the USBM process to the Yugoslav shales and then of developing a plant for commercial exploitation.

Economic studies should also be undertaken from time to time to reveal the comparative feasibility of using oil shales as a source of liquid fuel. Such studies can reflect the most likely technical processes available at the time and can thus put these sources of fuel in their proper perspective within the framework of the national economy and the national defense. The economic analysis would presumably include a comparison between oil shale, petroleum and possibly other sources of liquid fuels both as regards the investment cost and the cost of production.

Appendix 10 lists the specific ways in which it is hoped the Bureau of Mines can be of help to the Yugoslav scientists, including advice in the mining and processing of shales, training of one or more engineers and technicians, the supply of certain equipment, and the provision of literature.

The needs outlined in the appendix and the plan of procedure would seem to have merit and should be given such weight as the government attaches to the investigation of its oil shale resources.

A P P E N D I X I

Energy Resources Conference, Belgrade, February 9 to 11, 1953

Summary Report prepared by Ing. Slebinger

The Institute for Technical and Economic Research made arrangements and convened the conference with the following agenda:

I Problems involved in inventorying of energy resources of Yugoslavia

II Problems on the cost and economic feasibility of electric energy

III Possibility of export of electric energy from Yugoslavia

The conference was held in the Serbian Academy of Science on February 9th - 11th, 1953 at 9-13 and 17-21.

In connection with item I of the agenda (attached hereto) the conference was attended by directors of the electric systems of all Republics and their most competent experts on the above problems, counsellors with the Institute of Planning, the director of the Geological Institute of Yugoslavia, experts with the Institute of Geophysics, experts in geology of fossil fuels, experts for the investigation of quality of coal, experts on hydrology, and experts on working out of energy resources records. In connection with items II and III the most competent experts were present from the whole country from the corresponding hydro-electric design offices and from the institutions and bureaus for power development. The conference was also attended as guests by Mr. Warren H. Marple and Mr. A. V. Karpov, United Nations Technical Assistance experts in Yugoslavia.

For the conference the following papers were prepared and printed:

I On the problem of inventorying of energy resources of Yugoslavia:

1/ W. Marple: An Energy Resources Program for Yugoslavia

2/ Ing. V. Mikinecic: Brief Survey of the Geology of Fossil Fuels of Yugoslavia

3/ Dr. Ing. V. Slebinger: Some Problems in Inventorying "Gross" and "Net" Hydroenergy

4/ Two large wall maps, one covering the geology of fossil fuels and another covering all hydro plants in Yugoslavia that have been designed to date.

II The problems of cost and economic feasibility were discussed and treated by an ad hoc commission.

III On the problem of export of electric energy the following papers were prepared and read:

5/ Ing. A. V. Karpov: Export of Electric Energy from Yugoslavia

6/ Ing. J. Jerić: Possibilities of Export of Electric Energy from Yugoslavia to Italy

7/ Ing. V. Korosec: Electric Activities of Austria.

The director of the Institute of Technical and Economic Research, Ing. Stjepan Han, opened the conference at 10.30 a.m. (on February 9th, 1953) and outlined the problems to deal with and the agenda.

In the morning the papers under (1) and (3) were read, in the afternoon the paper under (5). Discussion followed and the following commissions were formed to work out proposals on further work and its organization:

a/ Commission for inventorying of hydro power resources ("gross" and "net" power)

b/ Commission for inventorying of fossil fuels

c/ Commission for investments and economic feasibility

d/ Commission for balancing of electric energy in Yugoslavia and for the analysis of foreign markets

e/ Commission for the transmission of electric energy

f/ Commission for inventorying of wind resources in Yugoslavia.

These commissions held separate meetings on February 10th, 1953 in the afternoon and reported their conclusions at the morning session of February 11th.

In the morning, February 11, 1953, Ing. J. Jerić read his additional paper which was a supplement to that under (6). Afterwards, the export of electric energy was discussed.

The discussion was led by Dr. Ing. V. Slebinger.

In the same morning of February 11th, Ing. S. Han presided a special conference attended by the directors of the Electro-systems. The conference discussed the problem of the organization of a future union of electric enterprises and institutions in the individual Republics. Such a union should coordinate the work among the Republics, determine general methods to be used in the establishment of economic feasibility and tariffs, and should represent their members in foreign countries and at international conferences.

On the same day (11-II-1953) in the afternoon the conclusions of the commissions (a - e) were read and followed by a discussion. It was proposed unanimously to form commissions of experts who will work out reports on the problems posed within an appointed time. Financial funds and the composition of the commissions were also proposed.

The plenary meeting entrusted Ing. Brelih to work out the statute of the union of electric enterprises. The plenary meeting stressed that the need for the formation of such a union had existed since the business of electric enterprises had been decentralized. Since then the need had appeared for the coordination of the common important problems, especially to form a body who could represent the electric branch of the national economy in various international organizations.

The work of the conference was useful, because it outlined the basic problems existing in the Yugoslav electrical economy of technical, economic and organizational nature, and worked out proposals for future work.

Belgrade, February 12, 1953.

A G E N D A

of the conference to be held in Belgrade

on 9, 10 and 11 of February 1953

I. Inventorying of energy resources.

A. Water power.

1. Methods for inventorying of "gross" and "net" water power

2. Measuring of streamflows in the Karst

B. Fossil Fuels

1. Methods for inventorying of fuels reserves

2. Programme of geological and geophysical exploration work

II. Methods for determination of cost of projected power plants

1. Selection of a general method for the determination of investment needed for the construction of power plants.

2. Selection of a general method for the determination of economic feasibility of the projected power plants.

III. Possibilities for export of electric energy from Yugoslavia.

1. Production and consumption of electric energy in Yugoslavia and future development.

2. Appraisal of future possibility of absorbtion of our electric energy abroad (Austria, Italy, Germany, Greece).

3. Techn.-econ. problems involved in the transmission to large quantities of el. energy to longer distances.

IV. Organization of the future work on some aspects of our power development.

1. Organization of the work on inventorying of energy resources.

2. Organization of the work on formulating of a general method for finding out of the econ. feasibility of power plants.

3. Organization of the work of a joint treatment of the problems on export of electric energy from Yugoslavia.

APPENDIX II

Proposals of the Committee on Hydro

1. It is proposed to form a Subcommission for hydropower which will be part of the Commission for energy resources formed with the State Department of National Economy. The task of the Subcommission will be to take care of the development of studies and utilization of water power; at the same time the Subcommission will make the proposals thereupon to the State Administration. The Subcommission will consist of experts in the field of water power utilization. They will meet at definite time and beside that if necessary:

2. The inventorying of water power should be done in two steps (stages, parts):

a/ Inventory of natural hydropower, i.e. of hydro-energetic potential.

b/ General plan of the utilization of available hydropower.

Enough work has been done to date on both inventories, particularly on the inventorying of natural hydropower. This work should be carried on systematically. The Hydroenergetic Institute "Jaroslav Cerny" is asked to submit a report which will show the present status of thework on inventorying of hydropower. The Institute will also propose the methods for the study of our water power and the form in which our hydropower will be presented. The Institute is asked to do that until May 15th. The basic data which are necessary in the study of hydropower are hydrologic data. The hydrometeorologic service which collects and treats such data, is not abreast of requirements, either with regard to the volume of the work done or its quality. Therefore it is indispensable and urgent to extend the hydrometeorologic service and to improve it.

It is recommended that the Federal Administration of the Hydrometeorologic Service should work out a program for strengthening and improvement of its service in all respects.

Belgrade, February 12, 1953.

APPENDIX III

The Use of "Gross Water Power" in Determining Potential Hydro Resources

(From an unpublished paper by Dr. Ing. Vladimir Slebinger, Institute for Technical and Economic Research, Belgrade)

1. An estimate of the gross water power of Yugoslavia

In order to establish the gross water power available, regardless of its economic value or possibility of utilization, it is only necessary to have physical data on river profiles and discharge. Gross power is defined as the total power available in a stream assuming 100% efficiency, according to the formula P equals 9.8/HQ. Accordingly, with a minimum of basic data, it is possible to arrive at an upper limit of the hydro resources of a country and their geographic distribution.

The first tabulation of Yugoslav waterpower was compiled by Bernacky in 1922. His data were based mostly on the estimated river flows, the exact data for which were unknown at the time.

Flows of the main rivers are now much better known and possible errors are considerably smaller. The following tabulation uses only arithmetical mean flows, for which rather reliable information can be obtained.

GROSS WATER POWER OF YUGOSLAVIA

A. The Danube River and Tributaries in Yugoslavia - Black Sea Drainage Area

		Billions of kilowatt-hours per year
DANUBE		
	(a) The Danube within Yugoslavia (from the point where it enters Yugoslavia to basins where it begins to form the boundary to Roumania) has a kinetic energy of 4.9 billion kilowatt-hours per year.	4.9
	(b) The Danube which forms the border with Roumania (including the Iron Gate) has energy of 17.9 million KWhs, of which the Yugoslav share would be half or 8.95 million KWhs.	8.95

		Billions of kilowatt-hours per year
DRAVA		
	(a) From the Austrian border near Dravograd to the Mura River, Yugoslav part of the river.	7.55
	(b) From the Mura River to the Danube, Yugoslav part of the river.	1.86
MURA		
	From Spilje to the mouth, Yugoslav part of the river.	1.45
SAVA		
	From its source to the Kupa River including tributaries, about	2.30
KUPA		
	With its tributaries Dobra, Mreznica and Korana	2.80
SAVA		
	From the mouth of the Kupa River to the Danube	2.63
UNA		
	(exclusive of its tributaries)	2.32
SANA		
	(" " " ")	0.92
VRBAS		
	(" " " ")	2.14
PLIVA		
	(" " " ")	0.18
BOSNA		
	(" " " ")	3.56

	Billions of kilowatt-hours per year
Tributaries of the BOSNA River (main tributaries)	1.60
The Upper Drina (Tara) from its source to Seepanopolje (Stephenfield) (Exclusive of tributaries)	2.22
DRINA	
From Seepanopolje to the Sava River (Exclusive of tributaries)	9.05
LIM	
(exclusive of tributaries)	2.55
PIVA	
(" " ")	2.22
CEOTINA	
(" " ")	0.82
UVAC	
(" " ")	0.79
THE BIG MORAVA	
(" " ") from Stalac to the Danube	1.71
THE SOUTHERN MORAVA	
(exclusive of tributaries)	0.99
THE WESTERN MORAVA	
(" " ")	0.84
IBAR	
(" " ")	1.33
NISAVA	
(" " ")	1.37

		Billions of kilowatt-hours per year
TIMOK		
	(exclusive of tributaries)	0.47
	Total Black Sea Drainage Area (8.22 million average kilowatts)	71.95

B. Drainage Area of the Adriatic Sea

SOCA	and its main tributaries, (Yugoslav part)	2.68
REKA	(Timava), down to sea level with its underground course	0.46
RIJECINA		0.34
LOKVARKA, LICANKA, KRIZ, POTOK, POTKOS, (VINODOL)		
	using the total drop to sea level	1.49
RUCICA, OTUCA, etc.		
	using all the head to sea level	1.23
ZRMANJA		0.29
KRKA		
	inclusive of its tributaries	1.00
CETINA		
	" " " " in the large Karst fields	5.30
NERETVA		
	(exclusive of its tributaries)	4.28
RAMA		0.92
	Tributaries of the Neretva and Rama to the Doljenka	1.69
	Tributaries of the Neretva from the Karst region downstream of the Doljenka about	2.00

	Billions of kilowatt-hours per year
TREBISNICA	
From Gatacke Field down to the sea level	2.68
THE BOJANA RIVER	
Drainage area (drainage areas of Scadarske) Scutari (Lake of the Zeta and Moraca Rivers)	2.30
CRNI DRIM	
From Prespanske Lake to the Radika River	0.90
RADIKA	
inclusive of its tributaries	0.95
BELI DRIM	
" " " " down to Vrbnica (border)	1.30
Total Adriatic Drainage (3.5 million average kilowatts)	30.06

Note: Only that energy of the Karst rivers has been included in the above calculation which relates to the surface water; underground tributaries which cannot be captured have been omitted.

C. Drainage Area of the Aegean Sea

VARDAR	
From its source down to the Greek border, exclusive of its tributaries	2.46
TRESKA	
(exclusive of its tributaries)	0.59
PCINJA	
(" " " ")	0.21

	Billions of kilowatt-hours per year
BREGALNICA (exclusive of its tributaries)	0.76
CRNA REKA (" " " ")	0.98
Major tributaries of the Vardar and Strumica River (Lepenac, Markova Reka, Toplica, Babuna and Bosava)	0.75
Total Aegean Drainage	5.75
Total of the Above (12.3 million average kilowatts)	107.76

The remaining smaller rivers (such as the Mlava, Pek, Porecka Reka and Nora Rivers, the left-bank tributaries of the Drava River, tributaries of the Sava River downstream of the Kupa, tributaries of the Una, Sava, Vrbas, Lim and Piva Rivers, the Crni, Beli, Veliki and Mali Rzav, Jadar and Kolubara Rivers, tributaries of the Ibar River, smaller rivers of Serbia and Macedonia etc.) amount to about 2 million kw., i.e. to about 17.24 billion kw. per year.

Summarizing, the total kinetic energy of water in the streams in an average year in Yugoslavia amounts to about 125 billion KWhs, or in terms of average power, 14.3 million kilowatts. This is the extreme upper limit of hydropower, only a fraction of which can be economically utilized.

2. Relation between "gross" and "net" water power

In 1952, the total world output of electric energy reached in round figures, 1,000 billion kwh. European production, which amounted to a quarter of the world output, should be increased by 100 billion kwh by 1956. Such an increase will involve a tremendous expenditure in the building of hydro and thermal plants. The conclusion may be reached on the basis of present studies that Europe can attain an ultimate "net" hydro output of 509 billion kwh per year (Economic Bulletin for Europe, 2nd quarter 1952).

The "gross" hydropower, i.e. the total energy of all running waters of Europe, is estimated at 1,800 billion kwh, so that the net utilization amounts to 509:1800 or 28 per cent.

It is interesting how the concept of the usableness of water power has changed with the passage of time. In Switzerland, for example, some time before World War I, it was thought that only 430,000 kilowatts could be utilized economically. In 1914 they raised this to about 1 million kilowatts. At present they estimate that 3.2 million kilowatts of mean power could be utilized.

Italy asserts that it has already developed over 60 per cent of its usable water power, and that only the more expensive plants remain to be built.

Similarly, in the United States, the proportion of its gross water power which is regarded as economically usable is continually being raised, owing both to a rapid increase of demand and to improvement in technology.

The overall efficiency (etatot), i.e. the relationship between the "net" hydroenergy which can be generated and the "gross" energy of a river system depends on:

(1) the proportion of available stream flow which reaches the turbine - eta Q.

(2) the quantity of available head which is utilized by the turbine - eta H

(3) the efficiency of the turbine - eta T, the generator eta G and the transformer - eta Tr, and

(4) the efficiency of transmission - eta L

The following table gives several typical cases and illustrates the gradual development of the technology of water power utilization:

Type of plant	eta Q	eta H	eta T	eta G	eta Tr	eta L	eta Total
(a) Early type plant Q1 = Q10	0.33	0.92	0.75	0.90	0.98	0.90	0.18
(b) Modern run of river plant Q1 = 1.2 Qsr	0.72	0.97	0.89	0.96	0.99	0.93	0.55
(c) The same plant as (b) but with regulated flow Q1 = 1.45 Qsr.	0.87	0.97	0.89	0.96	0.99	0.93	0.66
(d) Storage plant in an integrated system Q1 = 1.75 Qsr and up	0.96	0.97	0.90	0.97	0.99	0.94	0.75

After modern turbines had been developed, no substantial increase of efficiency could be expected with regard to intakes, electrical machinery and transmission system. The total efficiency can be raised only by reducing water losses through spills. That can be done if the streamflow is regulated by storage and if extensive integration is provided in large electrical systems. Multi-purpose water development schemes permit the best utilization of available water both for the generation of power and for other purposes. If the headwaters are regulated by storage reservoirs and if high flows are evened out, the lower reaches of streams can also be utilised economically, especially if navigation comes into consideration. When everything is considered, we see that the utilisation of water power gradually extends over entire river systems from mountain brooks down to the mainstem.

In Yugoslavia, hydroplants such as Tito, Doblar and Plave (with no storage) shows an overall utilisation of 56 per cent, and those on the Drava 60 per cent, also with no storage basins. A good illustration of plants with small storage is provided by the Dobra-Mreznica-Korana River system, where an overall efficiency of about 65 per cent is attained. Mavrovo and Vinodol storage projects approach the highest percentage attainable, i.e. about 75 per cent.

An important feature of Yugoslav rivers is that they are rich in water in the winter months (October through March) contrary to the pattern of Alpine and Scandinavian rivers. If transmission lines are built, these winter water masses will represent valuable energy for integration. Thus, winter overflows will be reduced to a minimum. That means that larger installations will be made where large quantities of winter water occur.

The producing capacity of Yugoslav hydroplants both projected and under consideration amounts to about 42 billion kilowatt-hours. Many river systems have not yet been studied. In the opinion of the Yugoslav designers, the total net energy that can be attained in Yugoslavia within the limits of economic feasibility, amounts to 50 billion kilowatt-hours. The gross hydroenergy of all streams of Yugoslavia being about 125 billion kilowatt-hours, the above quantity of 50 billion would represent a total utilization of 40 per cent.

A P P E N D I X IV

PARTIAL BIBLIOGRAPHY OF PUBLISHED AND UNPUBLISHED DATA ON YUGOSLAV HYDROPOWER

No.	Publication	Publisher and year of publication	Content	Language
	A- Inventory of Streams			
1.	Inventory of streams of the Kingdom of Serbians, Croates and Slovenians	Main Water Board, Belgrade, 1924	Inventory of streams starting from those 10 km long and up and including all their features (length, drainage area); a map and longitudinal profiles are attached	Serbian
	B- Mapping of Streams (published and unpublished)			
2.	Maps and profiles of the Great Morava, the Southern Morava, with Binacka, the Western Morava, the Ibar and the Danube Rivers	Main Water Board, Belgrade 1924-1927	Technical report, a map, longitudinal profiles and cross sections geologic map and typical profiles	Serbian
3.	Longitudinal profile & cross sections of the Danube River	Budapest, 1905	Plan, longitudinal profiles & cross sections of the Danube River	Hungarian
4.	Longitudinal profile and cross sections of the Tisa River (section Tisbetch-Segedin)	Budapest 1934	Plan, longitudinal profile & cross section of the Tisa River	Hungarian
5.	Mapping of the rivers Nishava (1924), Brina (1926-1929), Vardar (1926), Ptchinya with the Kumanovska River (1927 and Drava (1930)	Unpublished	Technical report, map longitudinal profile and cross sections, detailed plans	Serbian

No.	Publication	Publisher and year of publication	Content	Language
6.	Local plan with profiles of the Drina River (1, 2, 3 and 4)	Unpublished	Suitability of Drina for floating of timber	Serbian
7.	Mapping of small streams in the drainage area of the Great and Southern Morava (47 streams), Western Morava (20 streams), Ibar (12 streams) and Nishava (9 streams)	Unpublished	Technical report, map, profiles and detailed plans	Serbian
	C- Annual Reports			
8.	Reports on precipitation, water stages and stream flows	Main Water Board with the Ministry of Public Works, Belgrade	Daily osbservations made at rain and stream gaging stations, data on the measurement of water quantity. Attached are a map showing rainfall, a map showing the distribution of gaging stations, and graphs of water stages.	Serbian
9.	Water stage observation in 1940	Zagreb, 1942	Daily observations of water stages, made at gaging stations. A map is attached showing the distribution of gaging stations. (Serbia, Montenegro, Macedonia and Slovenia are not included).	Croatian
10.	Documents pluviometriques et Hydrometriques du Royaume des Serbes, Croates et Slovenes	Main Water Board, Belgrade, 1923	Preface to the report on water stages and rainfall in 1923	French

No.	Publication	Publisher and year of publication	Content	Language
11.	Hydrologic Yearbooks (from 1941 to 1950) (Book VII)	Federal Hydrometeorologic Service Administration, Belgrade, 1947-1952	Daily observations at water stream gaging stations, observations of ground water, water temperature. Attached are a map showing the network of gaging stations, and graphs of water stages.	Serbian
12.	Water stages and precipitations (rainfall) (from 1888-1916)	Budapest, 1893-1917	Daily observations at rain and stream gaging stations with many graphs. Included are: the Danube from Bezdan down to Orshava, the Drave from Donji Miholjac down to Osijek, the Sava from Zagreb down to Mitrovica, the Kupa from Karlovats down to Sreditcka, the Tisa from Senta down to Titel	Hungarian
13.	Observations of rainfall and water stages in the Kingdoms of Croatia and Slovenia (from 1894-1913)	Civil engineering Department of Croatian and Slovenian Kingdoms, Zagreb, 1898-1914	Daily observations of water stages and rainfall. Attached is a map showing the location of rain gaging and (stream) gaging stations. Covered is the territory delimited by the Drava down to Osijek, by the Danube down to the mouth of the Sava, by the Sava down to Jasenovats, by the Una down to Srb, by the Zrmanja down to sea level (Adriatic Sea), farther the border goes along the sea coast up to Rijeka, crosses Milanov vrh, follows up the Kupa River to Virodin, the Sutla upstream to Miljan and farther up to the Drava northwest from Ormoz.	Croatian

No.	Publication	Publisher and year of publication	Content	Language
14.	Jahrbuch des K.u K. hydrografischen Central-Bureaus (1895, 1897-1909, 1912, 1913)	Hydrographic Service of Austria, 1897-1917	Daily observations of water stages and rainfall, water temperature, duration of water stages. Attached is a map showing average rainfall and the location of hydrometeorologic stations. The territory treated as that whose limit goes up from Adriatic, crosses Visotchitsa, turns eastwards to Mlinishte, then to south - east across Byelashnitsa, southwards to Triglav, then to the south till Oryen and down to sea near Sutomer from where it goes along the seacoast up to Visocica.	German
15.	Annali idrologici (1927, 1929, 1936)	Ministry of Public Works, Rome 1930, 1939, 1941	Daily observations of water stages and rainfall, water temperature, oceanography. Includes data on the measurements of alluvion. Covers the territory from the source of the Sotcha down to its mouth then along the sea coast to Rijeka, then across Postojna up to the source of the Dolinka River.	Italian
16.	Report on duration and frequency of water stages and on streamflows for large and minor rivers of Yugoslavia	Ministry of Public Works, Hydrotechnical Department, Belgrade, 1936-1938	Durations and frequencies of water stages, stream flow with corresponding graphs for the following large rivers: the Danube, Drava, Tisa, Sava and Morava, and for the following minor rivers:	Serbian

No.	Publication	Publisher and year of publication	Content	Language
			the Kupa, Una, Vrbas, Bosna, Drina, Piva, Lim, Kolubara, Souther Morava, Nisava, Western Morava, Ibar, Mlava, Pek, Timok, Tamis and Vardar	

D- General Stream Flow Records of Yugoslavia

No.	Publication	Publisher and year of publication	Content	Language
17.	General stream flow records for the rivers: Danube, Tisa and Sava	Federal Hydrometeorologic Service Administration, Belgrade, 1952	Technical report, a map showing average precipitation, tables covering stream flows & graphical representation of hydrologic data	Serbian
18.	General stream flow records for the rivers: Timok, Crni Timok, Veliki Timok, Mlava, Pek, Drina	Federal Hydrometeorologic Service Administration, Belgrade, 1952	Technical report, a map showing average precipitation, tables including stream flows & graphical representation of hydrologic data	Serbian
19.	Hydrologic data on the Sava Dolinka River	Ministry of Public Works, Ljubljana, 1947	Hydrologic data on the Sava Dolinka inclusive of graphical representation of hydrologic data	Slovenian
20.	Runoff of some major tributaries of the Sava from Radovljica downstream to Catiz	Hydrometeorologic Service Administration, Ljubljana, 1947	Discharges of some major tributaries of the Sava in the Radovljica-Catez reach (river section). Hydrologic data are graphically represented.	Slovenian
21.	The Sava River from Radovljica down to Radece	Hydrometeorologic Service Administration, Ljubljana, 1947	Hydrologic data on the Sava River from Radovljica down to Radece. Graphical representation of hydrologic data is included	Slovenian

No.	Publication	Publisher and year of publication	Content	Language
22.	The Middle Drina (hydrologic report)	Hydroelectro project Belgrade, 1947	Hydrologic report to the basic plan of water power development scheme of the Drina River including numerical and graphical data	Serbian
23.	A study of the stream flow of the Drina at Zvornik	Hydroelectro project Belgrade, 1952	Technical report inclusive of graphical representation of hydrologic data	Serbian
24.	The Lim River	Hydroelectro project Belgrade, 1947	Hydrologic report introducing the basic plan of power development of the Lim River and its tributary Uvac. Graphical representation of hydrologic data is included.	Serbian
25.	Variations of stream flows in the rivers Western Morava, Rzav, Lim, Uvac and Great Morava	Federal Hydrometeorologic Service Administration, Belgrade, 1948-1949	Technical report: a map of the drainage basin including average rain fall, hydrologic data (graphs) are included.	Serbian
	E- <u>Water Power Records</u>			
26.	Preliminary inventory of water power of the Kingdom of Serbians, Croates and Slovenians	Main Water Board Belgrade, 1921	Technical report including graphs and a map of water powers	Serbian
27.	Records of water power of Yugoslavia in the drainage basins of the Western Morava, Southern Morava, and Drina Rivers inclusive of their tributaries; of the Vardar and Treska rivers; water power records of the Great Morava	Federal Hydrometeorologic Service Administration Belgrade, 1928-1950	Technical report: a table showing stream flows and graphs thereof; profiles including water power of the individual streams	Serbian

No.	Publication	Publisher and year of publication	Content	Language
28.	Water power of the rivers Catina (inclusive of the karst fields), Neretva, Rama, Una, with the Unac and Boana	Hydroenergetic Institute "Jaroslav Tcherny" Belgrade, 1951-1952	Technical report including all numerical and graphical data and a map of water powers	Serbian
	F- Periodicals and Studies			
29.	Hydrometeorological courier	Federal Hydrometeorologic Service Administration, Belgrade		Serbian
30.	The Courier	Federal Hydrometeorologic Service Administration, Belgrade, 1952		
31.	Navigation map of the Iron Gates (Djerdap) on the Danube River	Main Water Board Belgrade		Serbian
32.	Caverns in the vicinity of Osijek, Velika Paklenica and Zamet	Geologic Institute of Yugoslavia, Belgrade, 1938		Serbian
33.	Work on the study of a general regulation of the Danubian sector "Djerdap" (Iron Gate)	Main Water Board Belgrade, 1924	8 volumes of technical reports on the regulation of the Iron Gates	Serbian
34.	Statistics and considerations on the traffic in the "Djerdap" sector	Main Water Board Belgrade, 1924		Serbian
35.	The Danube, its economic and cultural function in Central and Eastern Europe	Vienna, 1932		German

No.	Publication	Publisher and year of publication	Content	Language
36	Etude sur le Régime des glaces du Danube (A Study on the regimen of ice on the Danube)	Rome, 1934		French
37.	Zur Hydrographie des Cerknisko Polje (Hydrography of the Cerknisko Field)	Belgrade, 1934		German
38.	The traffic on the waterways in 1923, 1924 and 1925	Main Water Board Belgrade, 1934		Serbian
39.	Report on the regiment of ice on the Yugoslav section of the Danube in the 1928-1929 winter	Ministry of Public Works, Belgrade, 1934		Serbian
40.	Report on the distribution of the precipitation by quarters and on the rainfall depth in the vegetation period in the Kingdom of Yugoslavia	Ministry of Public Works, Belgrade, 1937		Serbian
41.	Code for geodetic works	Main Water Board Belgrade, 1929		Serbian
42.	Report on the activities of the Main Water Board	Main Water Board Belgrade, 1921		Serbian
43.	A list of the works of the Main Water Board	Main Water Board Belgrade, 1928		Serbian
44.	Technical directions for the investigation of the Morave River	Main Water Board Belgrade, 1924		Serbian
45.	Compte-rendu de l'étude de la crue de 1926 dans le secteur Bezdan-Bukin (Report on the study of the 1926 high water on the Bezdan-Bukin section)	Main Water Board Belgrade, 1928		French

APPENDIX V

Commission for Fossil Fuels

Report to the Energy Resources Conference, Belgrade, February 11, 1953

The task of this commission is to propose a general methodology for the computation of the reserves of fossil fuels.

Considering the deficiencies and voids in the present regulations which relate to the manner of computing reserves, it is necessary to make a new general methodology which should, in the first instance, cover the following items:

1. The computation should include not only quantitative data on the size of reserves, but also data on the quality of the useful matter as well as information on the special distribution of the different kinds with regard to their technological properties. Further, the computation should include data on the geologic conditions of occurrence of useful matter and on other natural factors which determine the conditions connected with the work of mining and production.

2. Standards for the classification of reserves should be as specific as possible to reduce as much as possible the influence of the subjective elements. But the standards should not be so extensive as to render the exploration work too expensive or time-consuming. At the same time the standards should not be so general as to lessen the accuracy of the computations.

3. So-called "Out-of-balance" on untotalled reserves should be required to be computed. Limits determining such reserves with regard to the depth of the useful matter, the minimum thickness of the mineral deposit, the minimum content of the useful matter, etc., should be specifically presented.

The commission should also classify the deposits of fossil fuels on the basis of the geologic conditions which characterized the individual deposits. It should also work out detailed regulations and requests which govern the classification of the reserves for each category of deposits separately.

During their work, the commission should make a critical study and comparison of the present standards for the classification of reserves elsewhere in the world, and evaluate their deficiencies and advantages.

Organization of the work of the commission

The work on methodology will be organized in such a way that groups of experts should be formed by each republic. These groups, guided by the above-mentioned tasks, will make their own plans for proceeding with the above-mentioned tasks, and will discuss them later at the joint meeting where a general proposal will be made.

The groups formed by the republics should develop and complete their proposals in three months which will start from the day when this proposal is accepted by the plenary conference. The final proposal for methodology will be worked out in a time which will be determined later at a plenary meeting of the commission.

Cost of the work of the commission

The salaries for the work of the members of the commission will amount to about 1.700.000 dinars. The commission consists of 14 members; if the republican groups are included, then there are 23 members in total.

Explanation of the costs:

Travelling expenses..................	Din. 690.000.-
Daily allowances, 22 a 700 din:......	" 154.000.-
Honoraria to the collaborators, secretaries and other expenses.....	" 856.000.-
	Din.1700.000.-

Members of the commission

Belgrade:

(1) Ing. Popovic Boza
(2) Ing. Blazek Aleksandar
(3) Ing. Mirkov Kornelije
(4) Professor Pavlovic Milos
(5) Ing. Vukanovic Branko
(6) Professor Proson Dragutin
(7) Geologist Mikincic Vjekoslav

Zagreb:

(1) Professor Ogulinac Josip
(2) Professor Rubinic Antun
(3) Ing. Kisic Petar

Sarajevo:

(1) Ing. Vragolov Niko
(2) Ing. Grujic Nenad

Ljubljana:

(1) Ing. Stokan Karlo
(2) Ing. Jeglic

Ing. Popovic Boza was proposed to assume the work on the scientific classification of coal with regard to its technological properties.

Ing. Mikincic Vjekoslav was proposed to organize the whole work of the commission.

In inventorying fossil fuels it will be indispensable to carry out as soon as possible the necessary geologic and geophysical explorations. Before the work starts, our institutes should be supplied with some additional geophysical instruments and our geologic and geophysical staff should be improved by sending some of them abroad to specialize and train. In that regard the assistance of the UNO should be very useful.

APPENDIX VI

Problems of Classification of Fossil Fuel Reserves

Statement by Ing. Vjekeslav Mikincic, Director of the National Geologic Institute, before the Energy Resources Conference in Belgrade, February 11, 1953

The results which have been achieved to date, though incomplete, are of great scientific and economic significance and point the way to be followed in our further work. It is necessary, however, that the results achieved be of use to the country in its further and proper economic development. Therefore, they must be expressed in terms of reserves of our mineral raw materials. Such a computation of reserves should provide the basis for establishing the extent of our mineral supplies which in turn will serve as the basis of our future economic development.

If we are aware of the importance of the mineral wealth than it is quite obvious that the problem of the exact computation of reserves and the problem of the methods used in the calculation are of primary significance. It appears, however, that this problem has been definitely solved either in our country or in other countries. For this reason, we believe that the problem of the methods which should be adopted in the computation of reserves, and in their classification, should be posed and some solution reached.

What does this problem consist of?

As far as we know, there are, broadly speaking, two classifications of mineral raw materials. According to the first classification, mineral deposits are divided into "visible" reserves, "probable" reserves and "possible" reserves. This classification, with a number of subdivisions, is used by most countries in the world.

According to the second classification, which is used in the Soviet Union, mineral reserves are divided into A1, A2, B, C1, and C2 categories.

If we compare these two basic classifications, we shall find that A1 and A2 categories correspond to "visible" reserves, the B category to "probable" reserves, and C1 and C2 categories to "possible" reserves. What then is the difference between the two classifications? Substantially, there is no difference in the classification itself. The difference appears in the criteria according to which given reserves are classified. In fact, the criteria determines the way in which reserves are computed, i.e. the methods used in their computation. Therefore it is not essential what we shall call the reserves. What is of essential significance is the conditions on which the classification is based, i.e. what elements must exist to allow us to classify a given reserve into one or another category. This is the question that has

to be solved, because the criteria used in the determination of categories is neither generally accepted nor precise, and this fact often gives occasion to everyone concerned with the computation of reserves to act subjectively when he has to decide into which category to include individual mineral deposits. Because of that, there is often no agreement in the appraisal of reserves as between different engineers, and this fact certainly renders the exactness of the estimates themselves rather doubtful.

In our opinion, which is based on experience gained to date, both the above-mentioned classifications are deficient as to the criteria adopted for the determination of mineral reserves.

The main deficiency of the first classification, which could be referred to as the English classification (its basic principles were determined by the Institute of Mining and Metallurgy in London in 1902 and 1912, and later were accepted and completed by specialized scientific institutes in Germany, the United States and other countries) is that the necessary elements governing the inclusion of a particular reserve into a given category are not precisely enough determined. This is particularly true for the "probable" and "possible" reserves. These two categories are conceived in a much too general and indefinite way. They are also lacking in concrete conditions which should specify the criterion for classification more exactly. This fact, in its turn, creates broad possibilities of acting subjectively in the computation of the reserves, which in turn often leads to considerable differences in the reserves computed for the same mineral bed by different estimators.

Another deficiency of this classification, so far as our conditions are concerned, is that the classification does not provide for a special category of reserves for these resources which as a practical matter cannot be exploited for one reason or another (depth of useful ore, very thin deposit, very low content of useful minerals, etc.). This is why there are considerable differences in the computation of reserves, especially of these of lower categories.

The Russian classification does not possess these basic deficiencies. It provides for precise conditions which govern the assignment of a deposit to a particular category. This classification also comprises a special category, the submarginal or so called untotalled reserves which include these mineral reserves that under present conditions cannot as a practical matter be utilised. It is obvious that this classification is more complete, which is why we adopted it in its entirety.

It has deficiencies, however, which reflect in the first instance in too rigorous demands imposed in the classification process. This is particularly true of the categories of higher rank. This classification demands for each type of mineral deposit, special conditions which permit the classification. These demands for higher rank categories are often so demanding that the expenditure for the realization of conditions imposed generally exceeds the value of the deposits themselves. Apart from that, the preliminary investigations called for by these regulations, demand so long a period of time that actual exploration is retarded.

These are the basic deficiencies of the present classifications of the mineral reserves, with regard to the methods used in the computation. There are also other deficiencies which are not of essential significance and which can be easily remedied by appropriate instructions.

As to our own needs, it is necessary to adopt a single general classification with clearly defined conditions for the categorization of reserves. The conditions should be so provided for, that the influence of the subjective elements in the computation of reserves could be reduced as to a minimum. Such conditions should not be so extensive as to increase appreciably the cost or to retard the exploration work.

The computation of the reserves should include not only quantitative data on the deposits, but also data on the geological position of the ore, its quality, the distribution of the different types of the same mineral ore on its physical and chemical properties, and other aspects which affect the conditions of mining and exploitation. That means that the mineral reserves should be not only a geologic concept but also a mining and technical concept. The classification itself should be based on a universal principle of computation. The classification must provide for definite rules and conditions which will define how reserves are to be computed with regard to the practical possibility for their exploitation, and will state what methods have to be used for the determination of each category, such as mining exploratory works, deep drilling, geophysical investigations or geological conclusions.

APPENDIX VII

Geology of Oil in Croatia

by

Naftaplin Zagreb

The northern part of Yugoslavia is chiefly covered by younger sedimentary deposits from all periods of the Cenozoic era. Such deposits over a large part of Yugoslavia extending from Slovenia on the west across Croatia and Vojvodina on the east, including the northern slopes of the hills of Bosnia and Sumadija. At certain places the sedimentary rocks form very thick beds, so that geologic formations sometimes exceeds the thickness of several hundred metres. There are many geologic structures there, some of them larger, other smaller. They all represent potential places for the accumulation of oil and gas. This possibility is indicated by the geologic form, stratigraphic composition, or existence of sand and sandstones, most of which structures are oil collectors.

In this area, the sources of oil and gas are connected chiefly with strata between the Mesozoic and Cenozoic, i.e. chiefly with Miocene and Pliocene, and to a smaller extent with Eocene. The oil and gas in exploitation at Gojlo, Lendava, Mramor Brdo, and Sumecani originate from these geologic formations, i.e. from their Torton and Abichi layers.

In addition to these younger geologic areas in the northern part of Yugoslavia, there are older sedimentary rocks - from the Paleozoic and Mesozoic era, which cover the whole southern and coastal belt, comprising parts of Montenegro, Hercegovina, Bosnia and the whole of Dalmatia, the Croatian Littoral and Istria. In these areas deposits more abundant and richer than those in northern Yugoslavia may be found owing to the nature and genesis of the deposits, namely, a large open ocean in the geologic past, extensive and deep sedimentary deposits, and favourable conditions for oil accumulation. This contrasts with the large closed sea, but smaller structures which are revealed in the geology of northern Yugoslavia.

Extensive exploration work is now being carried out in the Montenegrin Littoral. Depending on results achieved, the investigation may be extended to Dalmatia, the Croatian Littoral and Istria.

APPENDIX 8

EXPLANATION OF THE GEOPHYSICAL MAP

OF OBMURJE

Statement by Nafta Lendava /Slovenija/

Obmurje, which is presented on our geophysical map, geographically belongs to the southeastern part of the Slovenske Gorice. The Slovenske Gorice lie on the southwestern half of the map, stretching towards the Mura River Valley in low hills.

Geologically, this region belongs to the Graz Gulf which is one of the numerous gulfs of the Panonian Sea. This is a young Tertiary basin, delimited on the south by the Sava folds, on the west and north by the central Alps, on the east it opens into the Panonic Lowland.

The Graz Gulf contains Miocene, Pliocene and Holocene sediments. The sediments have been affected by some Pliocene folds. From our point of view, the most important was the Post-dacian folding. The origin of the so-called Selnice-Peklenica anticline and our oil deposits at Petisovci near Lendava can be connected with that folding.

On the extreme western edge of the map, Torton and Sarmat strata occur on the surface. The strata sink gradually in the eastern and southeastern direction under the Panonian sediments.

Geologist Dr. Moos determined the following regional boundaries of the formations in the Graz Gulf: the line Graz-Spilja separates the older Miocene strata from the Sarmat strata. On the west of this line, there are older Miocene strata with coal content. Silt also occurs there. On the east of the above line are the horizontal Sarmat strata.

The Sarmatic strata sink under the Panonian sediments near the Lendava Valley, somewhat east from the boundary between Yugoslavia and Austria and south from the Mura River, in the region east from Radgona.

Exploration and exploitation of oil wells have shown how the thickness of the Pliocene sediments grows in the eastern and southeastern directions.

The wells were drilled near Mureka Sobota. The western well met bedrock at 800 metres; the eastern well met bedrock at 1100 metres. They were both drilled through the Panon. Sarmat and Torton are not mentioned in the reports.

The reports say that the bedrocks are made of gneiss.

The Lendava well is drilled through the Panon at a depth of about 1800 metres. The Lendava Panon will probably be followed by the Sarmat about 200 metres thick, below which Torton is likely. This was established by drilling a well to the depth of 2500 metres.

In Hungary, the Panon is 2000 metres thick.

In the attached geophysical map we can see several anticlinal structures. Going from the northeast to the southeast, we can see the Radgona anticline first, at Strukovci.

The Sobota anticline follows. Its axis has a SW-NE direction. It stretches from the Videm village to Seboborci. At this anticline, one of the above-mentioned wells /near Murska Sobota/ was drilled and it reached bedrock at a depth of 800 metres.

Northeast from Murska Sobota lies the Bogonja anticline. On its southeastern flank the second well /near Murska Sobota, at Rakicane/ was drilled: it reached bedrock at 1100 metres. One the eastern and southeastern flanks of this anticline, Panon strata are supposed to be thicker. But these regions have not yet been investigated, though they are likely to contain some oil.

The Sobota and Bojina anticlines embrace the large Ljutomer syncline which lies between Ljutomer and Beltinci.

Very instructive for the whole area, particularly for the Lendava oil field, in the anticline which goes from Ormoz to northeast and turns southwest from Strigova and Selnica and Peklenica. The axis of the anticline sinks towards the east. Between Peklenica and Ormoz, straight along the crest of the anticline, low hills extend which enable the geologists to observe its structure. As the axis of the anticline goes down in the northeast and east direction, the oldest strata which form the anticline, i.e., its core between Ormoz and Strigove, become visible owing to the denudation phenomenon. Younger sediments follow in the eastern direction until they get covered over by Holocene alluvium, in the plain, east from Peklenica.

Torton appears on the surface in the area between Ormoz and Strigovo, followed by Sarmat in the northeastern direction and further east Panon overlies the Sarmat formation.

The exploratory deep well at Kog showed that Torton was about 800 metres thick and that probably Helvet was beneath it, but Helvet was not proven as no fossils were found. The well failed in the alleged Helvet after it had been drilled for about 700 metres.

Torton is formed of sandy marls and sandy clays, which contain layers a few centimetres thick of Leita limestone and calcareous sandstones. These sandstones are very hard. The marls contain many macro and microfossils.

Helvet is formed of dark, hard sandy marls, which are badly faulted. This tectonic fracturing of the structure makes drilling very difficult.

Sarmat, 200 metres thick, overlays the Torton, and Panon is above the Sarmat. On the crest of the Selnice-Peklenica anticline, are old oil fields /near Selnica and Peklenica/. Oil was obtained there from the Upper and Lower Panons. Panon lies in these areas rather shallow. The wells are 50 to 200 metres deep. Panon is formed of sandy loose marls and sandy clay with thinner horizons of flint sands and flint sandstones.

At Selnica, the Lower Panon in its Abichi stratum is oil bearing; at Peklenica, the Upper Panon in its Rhomboidea strata is also oil bearing.

At Selnica, in the Abichi stratum, there are two oil horizons lying at depths of 0-200 metres. The strata are five to six metres thick. From the end of the past century up to the present, about 130 shallow and 14 deep wells have been drilled there. Shallow wells, in most cases, do not exceed a depth of 200 metres, while deep wells go from 200 metres to 1100 metres. Thus, deep wells reach the Torton. So far, only one well is believed to give oil from the Torton. Most deep wells failed owing to poor and inadequate equipment. Now that more modern methods and more experience in drilling are at our disposal, we should investigate the deeper layers, because the Panon has already been explored there and rather exhausted. Perhaps it would pay to investigate the Panon on the southern flank of the anticline, where little has been drilled so far.

At Peklenica, the oil bearing sandy horizon lies in the Rhomboidea stratum. A hundred years ago, people began to exploit oil from this stratum which is about three metres thick. Altogether, about 70 shallow wells and 2 deep wells were drilled. The deep ones were negative.

The area east from Peklenica, towards the Hungarian border was explored by drilling four deep wells. No well gave positive results. Probably the wells failed because of technical deficiencies with the equipment.

More exactly and systematically were explored the Panon strata on the northern flank of the Selnica-Peklenica anticline. There, the strata formed a kind of terrace. On this terrace, the Petisovci /near Lendava/ Oil Field was developed.

In the Petisovci oil field the Panon is subdivided as follows:

Upper Panon -	Rhomboidea strata
Lower Panon -	Abichi strata
	Pre-Valentian strata

In the Lower Panon occur marls, marl sandstones and light grey, course grain sized and comparatively loosely bound flint sandstones which are oil collectors at Petisovci.

The strata of flint sandstones occur in series. The series are separated by thicker strata of marl. The series of sandstones have their particular names. The lowest of the Pre-Valentian strata are called the Petisovci strata. In the past, we distinguished five horizons. At present, we have established that only the first and, eventually, the second appear continually across the whole field; all the others occur more or less lens-shaped, therefore they are developed in each part of the field, sometimes even in each well, in a different way.

Our chief oil resources lie in the Petisovci strata, at a depth between 1600 and 1750 metres. The single sandy strata are six to ten metres thick.

Over the Petisovci strata, there is a 20 to 30 metres thick strata of marl, that we call Lendava marl. A sandy series called Lovasi series lies over it. The Lovasi series which has been investigated incompletely, contains chiefly gas and only infrequently oil. The series reaches from 1610 metres to 1525 metres.

The Petisovci strata and the Lovasi series belong to the Pre-Valetian strata.

Three series called Ratka series belong to the Abichi strata. They contain gas, especially in the northeast part of the Petisovci area and at Dolina. Their depth ranges from 1550 to 1230 metres.

The Lenti marl separates the Lovasi series from the Ratka.

The Paka series lies over the Ratka. It also belongs to the Abichi strata. The Paka contains gas at Dolina. In the Pestisovci area there is probably no more gas. The Paka lies at a depth of from 1000 to 1100 metres.

Single sand strata at Lovasi, Ratka and Paka are five to fifteen metres thick, sometimes even twenty metres.

The Rhomboidea strata which are developed predominantly from fresh water sediments. are not interesting for our oil as they have no suitable collectors. There are chiefly sands and sandy clays there separated by imprevious marls as in the lower strata. The Rhomboidea strata are 800 to 900 metres thick. A 30 metre thick Holocene alluvion lies over them.

Thus, we get oil and gas only from the Lower Panon. It would be very interesting to investigate Sarmat and Torton thoroughly and perhaps the strata below Torton, which are quite unknown to us at Petisovci. Such investigations are very expensive owing to great depths, and at the same time, we lack drilling rigs. This is because Miocane lies at a depth of more than 1800 metres.

As already known, the quality of oil is the better the lower are the strata from which it derives. That can be applied to our oil fields, too. From the young Rhomboidea strata at Peklenica we extract heavy asphalt oil (0,93), from the Abichi strata at Selnica and from the Pre-Valentian strata at Petisovci. Good paraffin oil is obtained (0,83). We expect a still better oil from the Miocene, provided that we discover it.

Geologist PLANICAR

APPENDIX IX

Statement on Technical Assistance

by

Institute for Geophysical Research, Zagreb

Needs for geophysical equipment with regard to the plan of development of oil production in Croatia 1953-1960

Extensive research work in the field of geophysical investigations and structural drilling has to be done in respect to the future production of oil in Croatia in the 1953-1960 period.

We think that it will be necessary to increase the existing capacities of equipment for the above period, and particularly for 1953, if we take into consideration the plan of investigations and explorations made by the geologists of "Naftaplin" Zagreb. Thus, geophysical research work will be carried out on schedule and in proper sequence with other work.

The following instruments and devices which would hasten the geophysical work, are very necessary and wanted:

1 "Worden" gravimeter
1 portable seismic apparatus, complete with spare parts
2 portable drilling rigs especially built for drilling seismic wells, mounted on a truck (e.g. Willys or Jeep pick-up)
2 portable motor drilling rigs
3 seismographs for measuring the speed at which the waves propagate in a well
2 drilling rigs for drilling up to 600 m. (Failing type for structural drilling)
1 drilling rig for drilling up to 1200-1500 m., of Failing type for drilling structural wells and those where the speed of seismic waves will be registered.

With respect to the above requirements, we give the following explanation:

Our institute has 3 gravimeters, but all three, being less exact in measuring, have a considerably smaller efficiency too. In a month's work, with our instruments, we achieve 600 points in the best case, while with "Worden" 750 points can be attained. Besides that, the metering

accuracy of "Worden" being 0.01 mgal, structures cannot be accurately established. These structures are sometimes of great significance in oil-bearing areas. In addition to all that, if we had an accurate instrument we should be able to start solving particular tectonic relations by gravimetric methods. The accuracy of our instruments is only 0.05 to 0.15 mgals per point.

At present, seismic investigations represent the most efficient and widespread method of geophysical exploration of oil-bearing areas. This method has been comparatively little used so far, partly because it did not give usable data and partly because it was very expensive. But in 1952 the situation changed, as the seismic methods gave better results, so that we expect that during the next years with some improvement we shall apply the seismic methods in large measures. We want to approach the degree of American geophysical investigations, therefore, it would be necessary to get one more seismic apparatus, because the two apparatus we have (one of them is rather heavy for our terrains), will not be able to correspond to all tasks imposed on them.

We experienced difficulty this year, as we had no seismograph for registering the speed of the waves in the wells. Thus we were not able to determine exactly how deep the reflexes were which influenced our interpretations by making them somewhat uncertain. This is why we need 3 seismographs for deep wells.

We attained little efficiency in measuring. The daily capacity of 0.5 km. against 5.5. sq. km. in the United States cannot satisfy us on the one hand because the investigations become rather expensive, and on the other because they take too long. The small capacity can be attributed to the fact that we have no suitable drilling rig for drilling seismic wells. In the best case, we can drill 3 to 4 wells 10 to 12 m. deep in a day, instead of 8 to 12 that we should drill. We plan two drilling rigs mounted on Willys Jeep or Pick-up Jeep and two portable motor drilling rigs mounted on sedan-chair for our three seismic teams. We do not think that we exaggerate, as a rig is necessary as reserve.

In our opinion, we need two drilling rigs for drilling up to 600 m. and one for drilling to 1200-1500 m. (altogether 3 Failing rigs). They will be used for structural drilling as well as for drilling wells where we could study the speed of propagation of the seismic waves.

It is true that the acquisition of the instruments and equipment is very important, but it is also true that it is important to have an experienced staff to handle the instruments. Therefore, we think that it would be useful if some of our younger engineers went to the U.S. to study the modern methods there and get familiar with them. For the time being, we propose three men to go abroad; two of them would study the seismic problems in connection with the exploration of oil fields; and the third (an electrical communication engineer) would go to a factory for seismic instruments.

Bozidar Zalokar
Chief Engineer
Institute for Geophysical Research
Zagreb

Zagreb, 1 November 1952

APPENDIX X

Report on the Oil Shales of Serbia

by

Ing. Dimitrije Matic
Director of State Undertaking "Rudnik"
(Bureau for mining, engineering and research)

Introduction

In the PR of Serbia, oil shales occur at several sites, chiefly at Aleksinac, Podvis, Bela Palanka (Mironovac), Trstenik, Veljevo, Raca, Kolubara, etc. The most important reserves, however, are those in the basin of Aleksinac, both as to the quantity and quality. If we consider the fact, first, that here the shale deposits go parallel with the brown coal seams, the exploitation of which tends to become more and more expensive because the seam sinks down to bigger and bigger depths; second, that by mining of the coal only, larger quantities of shales are wasted or future exploitation of the adjacent strata of oil shales become impossible or at least less possible, it is obvious that we are immediately interested in the oil shales of Aleksinac, especially if we take into consideration that it would be possible to mine both coal and shales together (or at least partially together and partially oil shales separately), because the ratio of coal to shale is at least 1:30. If this ratio is computed in calorific values, it will be 1:15 in favour of oil shales.

Nevertheless, investigation work and exploration of the Aleksinac basin have not been made in such a way and degree to permit the initiation of exploitation.

As to the geologic and mining exploration works and mining exploitation we could be able to carry out the work ourselves since our people have many years of experience in mining. Nevertheless, some technical assistance would be desirable. On the other hand, we need more technical assistance, as will be seen below in this report, for technical investigations as well as for the processing (retorting) itself of oil shales and crude oil.

Geologic and mining exploration works

The most comprehensive and detailed information among all geologic and mining reports on oil shales of the Aleksinac basin is undoubtedly that supplied by the German consulting engineer Dr. Beyschlag and by our geologists Dr. Lukovic and Pavlovic. All other reports generally rely on these studies. Therefore, it will be of some interest to outline briefly the results of these studies. According to Dr. Beyschlag, whose work was done during World War II, the deposits of Aleksinac belong to the Oligocene period. A cross-section of the deposits shows the following picture, from bottom to top:

50	meters	crystalline schists
50	"	red (ferruginous) sandstones
50	"	yellow sandstones
40-50	"	lower zone of oil shales
1	meters	brown coal
160	"	marlstones
2.6	"	brown coal
46.5	"	second zone of oil shales
75	meters	marlstones and sandstones
4.6	"	coal deposit
50-81	"	third zone of oil shales
9	meters	upper zone of marl
520-530	meters	total thickness

According to the analyses given by Prof. Beyschlag, the crude oil content of the tested samples amounts to 18% to 20%. This cannot be considered as the average, however, because Prof. Beyschlag made no test drill or exploring gallery through all oil shale deposits.

The deposits of coal and shale lie at angles of from 30 to 80 degrees.

According to the geologists, Dr. Lukovic and M. Pavlovic, the strata of the Aleksinac Tertiary above the crystalline schists look as follows, from bottom to top:

250-300	meters	red sandstones and conglomerates
30-150	"	micaceous sandstones, clays, etc.
200	"	clay, clay slates less or more bituminous
3-6	"	brown coal
50-100	"	oil shales
150	meters	marls, marl slates with sand and some oil shale

In 1947, Dr. Lukovic made seven drillings to a depth of 200 meters in the vicinity of Subotinac Village just at the point where oil shale deposits outcrop and where open-case mining operations started later with the purpose of exploiting the oil shales. On the basis of these drillings, open mining operations which go through the shales, and geological information, the reserves in the Aleksinac basin may be computed as follows:

Oil Shale Reserves in the Aleksinac Syncline

	Average oil content	Millions of tons
A Reserves	12 to 14%	1
	6%	2
	4 to 5%	8
	Total A Reserves	11
B Reserves	12 to 14%	289
	6%	558
	Total B Reserves	847
C Reserves	12 to 14%	300
	6%	700
	4 to 5%	192
	Total C Reserves	1,192
Total Aleksinac		2,050

During 1951 and 1952 four more shallow drillings were made in the area mentioned which was intended for the exploitation of oil shales by open-cast mining.

Attached are Tables A to E showing the cross-sections of these wells with the corresponding chemical analyses.

A number of deep drillings were made with the purpose of exploring the coal beds. Unfortunately, cores have not been analyzed. Only the shale from well No. 38 was analysed (see Table E) but it is regarded as typical.

The former Enterprise for Exploitation of Oil Shales of Aleksinat also made a number of exploration works by means of galleries in that section of the area where it was intended to produce shales later on. In Table D is shown the oil content of a test shaft cut through a part of the shale deposit from the so-called old pit. During the exploitation of coal a number of galleries had also been opened through the shale deposits.

As may be seen from the above, no systematic exploration has been made of oil shales in the basin of Aleksinac which could be used for an accurate determination of the reserves and their content of organic matter. Systematic investigations must be made if one wants to start exploiting the reserves with certainty.

For this reason it is intended to formulate in 1953 a preliminary plan of study of the Aleksinac basin. The plan will include both the

necessary geological and mining exploration works, and data for working out more final plans for the parallel exploitation of coal and oil shales.

To carry out these works and to make the plans, there are enough competent engineers in Serbia. Technical assistance could be used, however, for the introduction of heavy mechanization. It has been planned that foreign experts might be consulted towards the end of the year 1953. We expect that up to that date we shall prepare material for discussion.

Chemical and technological works

(See also the short statement on tar processing in Appendix XI)

A large number of chemical and technological experiments have been made on oil shales of the Aleksinac basin. The works, however, have not been carried out far enough to allow us to decide on a method of processing these oil shales.

We are going to give here a brief survey of all important chemical and technological work, and at the end we will indicate in which stage the works are at present and what should be the technical assistance from the United Nations.

Below is given the chemical analysis of a sample of the Aleksinac oil shale which can be considered as an average shale in this bed according to the analyses which have been made of cores and open mining operations to date.

Analysis of a sample oil shale after primary distillation (according to Fischer):

Crude oil	9.9 %
Semi-coke	77.95%
Water	7.0 %
Gas plus waste	5.1 %
	99.95%

Analysis of ash

SiO_2	48.35%
Fe_2O_3 plus Al_2O_3	32.68%
CaO	14.78%
MgO	2.15%
	97.96%

Analysis of gas

Quantity of gas per 100 grs of shale	3.6 cm3
CO_2	28.0 %
H_2S	10.2 %
Butane	16.9 %
Ethylene	1.4 %
CO	3.4 %
H_2	30.4 %

CH_4 plus	3.2 %
H_2	6.1 %
	72.6 %

Elementary analysis

C	H	N	S
18.51%	2.73%	0.8%	1.73%

The oil shales of Aleksinac have been evaluated several times abroad. As an illustration, reference may be made to the following two examples:

1. In 1935 the French company "La Grande Paroisse" processed about ten tons of the Aleksinac oil shale in their pilot plant of the "Grande Paroisse" type. The shales selected were those having 11% crude oil content according to Fischer. The report shows the rate of output with this experiment. It is known that with plants of such type recovery of more than 95% of crude oil can be obtained. The recovered crude oil had the following content:

gasoline up to 200° C	15.5%
petroleum from 200-220° C	3.0%
gas oil from 220-350° C	20.0%
	38.5%

The residue after the primary distillation was composed as follows:

paraffin	15 %
lubricating oils	25 %
residue	10 %
	50 %

The report does not include information on the quality of these products.

2. In 1949, the German company Lurgi A. G., Frankfurt, carried out a much more detailed analysis of the Aleksinac oil shales in their pilot plant Lurgi-Schweiser. They obtained an efficiency which according to Fischer amounted to 85.4% in the most favourable test, out of a gross oil content of 15%. Such a low output excluded this type of plant from further consideration. The result was as follows:

gasoline up to 200°	33.1%
gas oil from 200-300° C	42.7%
coke for electrodes	9.2%
	75.0%

The quality of these products were satisfactory.

In our country, no technological experiments have been made using recent principles of oil shale processing. Some further research was undertaken by students but results will not be considered here.

Retorting

In 1948 experiments were made with an experimental kiln six meters long, 1 meter wide, about 1 meter high. The kiln was very primitive. Actually, it was only a chamber with three walls, filled with crushed shales, and covered with impervious clay. A fire was built at one end, and at the other openings were made through which gases were drawn off and went into a primitive condenser passing across a fan. An overall efficiency of up to 70% was attained in this experimented plant (i.e. 70% of the analysis according to Fischer).

The above results encouraged the exploitation in larger kilns (8 x 2 x 30 m). The shale was mined from underground works and about 300 tons per day were treated. The output of oil, however, was only 30 per cent of the output obtained in the laboratory tests, according to Fischer. Only recently after some re-designing was it possible to obtain an efficiency as high as 45%.

Such low efficiency, of course, raised the unit cost so much that all work was discontinued. It was decided that further systematic geologic, mining and technological investigations should be carried out before deciding whether to attempt exploitation on a larger scale.

Refining of tars

It would probably be of some interest to mention here the results achieved in a Yugoslav refinery and those obtained by the German company Lurgi Ltd., Frankfurt-on-Main, Germany, in the refining of crude oil obtained from the Aleksinac oil shales. Crude oil resulted from from the Yugoslav kilns.

	Yugoslav refinery		Lurgi Ltd.	
	Method I	Method II	Method I	Method II
Gasoline	9.09%	25.5%	11.5%	31.8%
Motor kerosene	22.7	17.5	-	-
Gas and Diesel oil	39.3	23.3	26.4	42.0
Tractor oil	-	-	30.0	-
Paraffin	1.8	-	14.1	-
Fuel oil and coke	12.8	16.0	15.3	10.0
Waste and gas	10.8	17.7	2.7	16.2

The method I used in a Yugoslav refinery consisted of the primary and vacuum distillations, and extraction of paraffin from the last distillate. The residue was then cracked. With Method II, all crude oil was thermally cracked.

When Lurgi Ltd., used the Method I, they obtained gasoline up to 200° C and Diesel oil from 200-300° C. With normal distillation, they obtained tractor oil from 300-450° C. From the latter they extracted paraffin inclusive of organic solvents. With Method II, they first extracted light fractions, then they exposed the residue to thermal cracking.

So far as the quality of final products is concerned, it may be said here that the light fractions (gasoline) showed always rather a big percentage of viscous matter and sulphur, and relatively large waste when refined with the usual acid processes, while its susceptibility to tetraethyl lead treatment was quite standard. Heavy fractions (kerosene, gas oil and diesel oil) correspond to the standards for such products; they could be marketed without encountering great difficulty.

From the above, it may be concluded that more favourable results could be expected from the crude shale oil if it was produced with a better process. The kiln process used in Yugoslavia was very primitive.

Current program of work

Below is described the work which Yugoslav engineers are now engaged in order to arrive at the best methods for processing the Aleksinac oil shales. Technical assistance needed from the United Nations is then outlined.

In the first place, as already mentioned, systematic exploration work, i.e. geologic and mining works, should be carried out. For this purpose, a preliminary plan will be worked out which will embrace all geological and mining works for the Aleksinac basin.

(a) Retorting of oil shales - All research work elsewhere in the world concerning the processing of oil shales has been looked over. Reference may be made to the following sources which proved most useful:

"Second Oil Shale and Canel Coal Conference Glasgow, July 1950";

"The Oil Shale Industry of Europe", by Boyd Guthrie and Simon Klosky, 1951, US Bureau of Mines;

"Synthetic Liquid Fuels", US Bureau of Mines, Annual Report February 1951;

"Synthetic Liquid Fuels", US Bureau of Mines, Annual Report July 1952.

Oil shales have been most thoroughly investigated in the United States by the Bureau of Mines. Yugoslav engineers should aim to adopt the American methods. For one reason, the Yugoslav oil shales, especially those from Aleksinac, are very similar to those from Colorado with regard to the content of mineral and organic matter.

That is why Yugoslavs decided that they will build as their first pilot installation a "gas combustion" retort, having a capacity of 6 to 7 tons of shale per day. The retort will be almost the same as that which was tested by the Bureau of Mines and with which very good results were achieved.

The Yugoslav plant will be divided into two sections: the retort itself and the devices for the extraction of oil from gases which carry the oil-mist produced in the retort. The design of the retort is completed and the equipment is being manufactured.

There is, however, a detail in the construction on which there is no reliable information available, though in one of their reports the Bureau of Mines supplied some data. The question relates to the gas air mixer in the gas combustion process (mixing of recycled gas and air). This problem has not been solved yet in Yugoslavia.

As to the problems concerning the second part of the plant, i.e. devices for the extraction of oil from gases, Yugoslavs are in contact through Petroleum Machinery Corporation, New York, with Mr. Boyd Guthrie of the Bureau of Mines. Judging from a letter from Mr. Guthrie to the Company, it would seem that no definite solution has yet been found with regard to the choice of an apparatus for the extraction of oil from gases produced in the retort. In Yugoslavia, for the time being, two alternatives have been adopted: the first alternative is the same as the one described by the Bureau of Mines in its Annual Report dated July, 1952. The second alternative represents a modified proposal of a German company which deals with primary distillation of coal.

If the first alternative is to be realized, closer cooperation is desired with the Bureau of Mines and also assistance from its experts.

Technical assistance in retorting of oil shales - The following technical assistance in retorting of oil shales is desired from the United Nations:

(1) Designs and sketches for the construction of the gas-air mixer of the Bureau of Mines gas combustion retort;

(2) Equipment: 2 centrifugal separators, 1 gas blower and devices for extraction of oil from gases in the same way in which the Bureau of Mines does it. Daily capacity: 6-7 tons of shale;

(3) Corresponding measuring instruments;

(4) Technical description of the process, the equipment, and apparatus;

(5) Visit of one of our experts for a 2-3 months period at Rifle, Colorado to get acquainted with technical processes;

(6) After the Yugoslav pilot plant has been assembled and put in operation, an expert of the Bureau of Mines should come to Belgrade and Aleksinac for a stay of one or two months.

Here it can be mentioned that the Bureau of Mines agreed (as reported by the Yugoslav technical adviser with the Yugoslav Embassy in Washington, Mr. Gruden who was in contact with the Bureau of Mines) that a Yugoslav expert be sent to Rifle, Colorado, with the purpose of getting familiar with the technological processes. The Yugoslav Technical Assistance Administration engaged engineer Gruden to take all the necessary steps to accomplish the formalities required. Meanwhile, Mr. Gruden was appointed to a new duty. It appears that further steps were thereupon suspended.

(b) Refining of crude oil - Something has been done and some experience has been gained in refining of crude oil extracted from Aleksinac oil shale through the kiln process. Here, too, we wish we could benefit by Bureau of Mines experiences. This, of course, could be considered only after we have produced our first quantities of crude oil in the future pilot plant for processing of oil shales. We should be very grateful if we had suggestions thereupon from the Bureau of Mines experts who were engaged on this problem. Since the crude oil from Aleksinac shale has high paraffin content, we are interested in the technological process which would render it possible to obtain that valuable raw material.

Technical assistance in connection with processing of crude oil should comprise the following items:

(1) What recommendations do Bureau of Mines experts have as to how our crude oil should be processed and transformed into final products? What processes should be used?;

(2) Our method of processing crude oil would be thermal cracking, catalytic reforming and acid treating; for this purpose we need complete laboratory equipment.;

(3) One or two fellowships for our people who should work with the Bureau of Mines Department for processing of crude oil from shales;

(4) We should appreciate the judgment of British experts (Scottish Oils Ltd., and others) as well as that of German experts, on the most efficient method for the extraction of paraffin.

(c) Summary of technical assistance needed for oil shales in Serbia - As already stated in this brief report, our need for technical assistance from the UN with regard to oil shales could be summarized as follows:

Geologic and mining works

(1) For investigation work: 1 modern drilling rig for drilling from pit up to 100 m;

(2) For exploitation:

(a) Advice of foreign mine experts in the field of heavier mechanization which would be utilised in the parallel mining of coal and oil shale (probably at the end of 1953 or in the first half of 1954.);
(b) Fellowship for one of our mine engineers who should study the application of heavier mechanization (underground) in 1954;
(c) Literature dealing with this aspect of mining work;

Processing plant:

(1) For investigation work in the retorting of oil shales:

(a) Information on the construction of the air-gas mixer of the Bureau of Mines gas combustion retort;
(b) 2 centrifugal separators for the separation of crude oil from gases in the gas combustion retort or technical data on their construction;
(c) Description of the technical process and operation of the individual parts of the plant;
(d) Instruments for measuring temperature and gas quantity in this plant;
(e) Fellowship for a technologist for the retorting of oil shales at Rifle, Colorado in the second half of 1953;
(f) Literature;
(g) Visit of a Bureau of Mines expert in the middle of 1954.

(2) For refining of crude oil:

(a) Complete laboratory equipment for thermal cracking, catalytic reforming and acid treating;
(b) Fellowship at the beginning of 1954 with the Bureau of Mines at Laramie, Wyo.;
(c) Literature.

(3) Problems of laboratory analysis:

(a) Special laboratory equipment for the investigation of oil shales and crude oil;
(b) Literature;
(c) Fellowship with the Bureau of Mines.

(d) Minimum program of technical assistance for 1953

(1) Information from the Bureau of Mines on the construction of the air-gas mixer of the gas combustion retort;

(2) Information from the Bureau of Mines on the construction or purchase of the centrifugal separators for the gas combustion retort. The capacity should be 6-8 tons per day of Aleksinac oil shales;

(3) Fellowship for a technologist with the Bureau of Mines for the retorting of oil shales, second half of 1953. The Bureau of Mines has already agreed.

Ing. D. Matic

TABLE A

Analysis, After Fischer, of Well No.5
Aleksinac, 1951

Depth (in meters)	Tar (in %)	Water (in %)	Gas and Waste (in %)	Semi-coke (in %)
115.2 - 119.5	16.6	3.2	5.2	73.0
119.5 - 120.5	12.8	6.4	4.0	76.8
120.5 - 123.0	17.2	5.2	7.8	69.8
123.0 - 127.0	13.8	5.2	10.4	70.6
127.0 - 128.8	27.8	3.8	7.2	61.7
128.8 - 129.5	33.5	4.2	7.4	54.9
129.5 - 130.5	24.7	6.0	6.1	63.2
130.5 - 131.0	14.4	4.0	4.0	77.6
131.0 - 141.4	19.2	5.6	5.4	69.8
141.4 - 141.6	8.3	7.0	2.5	82.2
141.6 - 149.0	12.8	4.8	2.8	79.6
149.4 - 154.0	9.4	6.6	3.1	80.1
154.0 - 155.0	2.6	6.0	2.4	89.0
155.0 - 156.0	5.7	7.0	3.3	84.0
156.0 - 157.0	2.6	8.8	2.2	86.4
157.0 - 162.8	4.2	6.2	1.3	88.4
162.8 - 165.1	16.0	5.6	4.4	74.0
163.0 - 165.0	9.4	6.2	2.9	81.5
165.5 - 166.0	2.4	7.6	2.0	88.0
166.0 - 168.8	13.9	5.4	3.7	76.8
168.8 - 170.5	6.6	6.4	3.2	83.8
170.5 - 174.7	9.8	6.2	3.2	80.8
175.0 - 179.0	14.2	6.4	4.0	75.4
182.0 - 183.7	10.0	5.0	3.2	81.8
185.0 - 190.0	4.6	8.0	2.0	85.4

Source: Ing. Dimitrije Matic, Belgrade, 1951

TABLE B

Analysis of Well 6 and Well 7 - Aleksinac, 1947

Well 6

Depth (in meters)	Thickness (in meters)	Bitumen Content (in %)
34.8 - 35.4	20.6	12.50
35.4 - 42.3	6.9	7.75
42.3 - 52.5	10.2	3.85
52.5 - 56.1	3.6	8.75
56.1 - 59.5	3.4	2.50
59.5 - 68.5	9.0	8.80
68.5 - 72.0	3.5	0.70
72.0 - 85.0	13.0	5.70
85.0 - 89.0	4.0	12.80

Well 7

19.0 - 43.8	24.8	6.00
43.8 - 79.7	35.9	14.60
79.7 - 88.0	8.3	2.00
88.0 - 104.3	16.3	8.20
104.3 - 107.0	2.7	6.60
107.0 - 117.2	10.2	4.50
117.2 - 119.7	2.5	10.95
119.7 - 120.7	1.0	6.40

Source: Prof. M.L. Lukovic, 1947

TABLE C

Analysis of Well 6 - Aleksinac, 1951

Depth (in meters)	Tar (in %)	Water (in %)	Gas and Waste (in %)	Semi-coke (in %)
55.2 - 66.0	14.7	5.2	3.4	76.7
66.0 - 67.0	17.2	4.5	3.8	74.5
67.0 - 70.0	19.3	5.5	4.5	70.7
70.0 - 72.0	13.9	5.9	3.9	76.3
72.0 - 74.0	12.8	5.8	4.1	77.3
74.0 - 74.5	17.6	5.5	4.2	72.7
74.5 - 75.5	15.3	5.0	4.7	75.0
75.5 - 100.0	12.7	7.0	3.6	76.7
100.0 - 102.0	3.2	7.0	1.2	88.5
111.2 - 112.5	9.7	5.9	2.9	81.4
116.0 - 119.5	12.1	6.6	2.9	78.4
119.5 - 120.0	10.7	3.0	2.8	83.5
120.0 - 124.4	11.0	5.7	3.0	80.3
125.0 - 129.6	10.8	4.8	2.8	81.6
132.5 - 135.5	5.0	5.2	2.0	87.8
139.4 - 148.4	6.1	6.8	1.9	85.2

TABLE D

Analysis of Cross-Section of Shale Deposit Made from the "Old Pit" - Aleksinac, 1951

Oil	Oil
at 1 m - 15.0 %	at 18 m - 18.5 %
" 2 m - 10.5 %	" 19 m - 20.0 %
" 3 m - 15.5 %	" 20 m - 22.0 %
" 4 m - 18.0 %	" 21 m - 20.5 %
" 5 m - 10.0 %	" 22 m - 14.0 %
" 6 m - 25.0 %	" 23 m - 4.0 %
" 7 m - 26.5 %	" 24 m - 5.0 %
" 8 m - 21.0 %	" 25 m - 4.0 %
" 9 m - 14.5 %	" 26 m - 4.5 %
" 10 m - 20.0 %	" 27 m - 24.5 %
" 11 m - 14.0 %	" 28 m - 24.5 %
" 12 m - 15.0 %	" 29 m - 25.0 %
" 13 m - 13.0 %	" 30 m - 11.5 %
" 14 m - 23.5 %	" 31 m - 23.5 %
" 15 m - 27.0 %	" 32 m - 19.5 %
" 16 m - 20.0 %	" 33 m - 19.5 %
" 17 m - 26.0 %	

Source: Ing. Dimitrije Matic, Belgrade, 1953

TABLE E

Analysis of Well 38 - Aleksinac, 1951

Map coordinates

x = 4 827 739
y = 7 554 255

Elevation above sea level 258.60 m

Elevation above sea level (in meters)	Oil (in %)	Water (in %)	Coke (in %)	Gas and waste (in %)
399.00 - 404.00	11.2	4.2	80.9	3.7
404.00 - 408.00	9.7	5.0	81.4	3.9
408.00 - 422.20	23.1	5.0	67.8	4.1
422.20 - 428.60	15.2	4.4	76.8	3.6
428.60 - 435.00	7.8	4.6	84.4	3.2
435.50 - 441.00	9.0	4.6	84.4	2.0
441.50 - 454.60	10.1	6.8	79.0	4.1
457.60 - 465.10	10.4	5.0	82.0	2.6
465.10 - 475.00	7.2	6.0	83.2	3.6
475.00 - 488.15	12.5	6.0	78.1	3.4
488.15 - 492.00	12.7	5.2	79.3	2.8
498.20 - 501.20	21.1	5.2	68.6	5.0
501.20 - 507.50	19.1	4.2	71.0	5.7
522.00 - 528.00	10.4	4.4	81.4	3.8
535.00 - 537.90				

Source: Ing. Dimitrije Matic, Belgrade, 1953

APPENDIX XI

THE OIL SHALES OF YUGOSLAVIA

Possibilities of Exploitation

by

Dr. Ing. ALEKSANDAR PETRUSIC
Director of enterprise "Metan"
Katina Croatin

I. Processing the Aleksinac tars

...The tar should (1) be treated at the site only for separation of the basic groups (separation of paraffin). (2) Then it should be processed either in special refineries, where lower fractions should be recovered (the most important of them is for manufacture of motor fuel or cracking), or (3) it should be treated in special plants for the processing of tars. (4) The solid residue can then undergo hydrogenation, i.e., the crude paraffin should be refined and softened.

There is no recovery of lubricating oil from higher quality tars.

It is true that special derivatives, such as light gasoline and so on, could be recovered from the tars, but it would not be reasonable to start such production because these sources are too expensive and the output too small. On the other hand, the high-quality paraffin is a valuable material that can be used as motor fuel.

Residual gas: A valuable source of thermal energy is represented by the residual gas which forms after the primary distillation. The residual gas has a chemical composition similar to that of a good quality producer gas. There is information thereupon in the report of the German company Lurgi to which reference may be made for more detailed data. In any case it can be said that from a medium quality shale at least 1 cubic meter of gas can be recovered per kilogram, having a heat content of at least 1,000 kilogram-calories.

The residual gas can be utilized by the mining works in the first place, but also by power plants, chemical plants and metallurgical works in a word by all plants which use thermal energy.

Mineral residue: The mineral residue is of no particular value. It is true that experiments have been made with remarkable success, specially from the economic standpoint.

II. Sinj Shales

At the foot of the Kamesnice Mountain in the northeastern part of the Sinjako Polje (Sinj Field), a small basin is located through which the Huda River flows. This small basin represents the Sinj synoline where bituminous shales occur. The bed is 17 km from Sinj by road and less by airline.

Most useful and detailed information on the bed can be found in Prof. Margetić's report which was published in 1952. Parts of the report were also published in the Geological Courier, 1952.

The bed is formed of several parallel deposits and thin strata of bituminous shales. The shales are oily, black and shiny in colour. The mineral residue is made of cretaceous marl. The tar content ranges from a few percentage to above 30 per cent with high paraffin content. According to the statement of Prof. Margetić, the deeper deposits of oil shale become thicker, and what is most interesting, the water does not penetrate into them because of the pervious character of the karst ground. This latter property is very important when deeper horizons are exploited.

Reserves: Only a small part of the area has been explored systematically. The whole area should be systematically drilled first in order to obtain a real picture of the total reserves. The reserves are estimated for the time being to be 10 million tons, the probably reserves being at least double.

Exploitation is possible only with deep underground workings.

Character of oil shales: There are several varieties of oil shale in the Sinj Field. Nevertheless, all of them have a common feature, i.e. richer shales are subject to melting during the primary distillation, which is not the case with the Aleksinac shales. Therefore the problem of their processing is not so simple as at Aleksinac. This aspect indicates the need for caution in the selection of the processing method.

Large quantities of rich gas are recovered during the primary distillation.

The Sinj shale is characterised by high sulphur content. The mineral residue is of marl character. All analyses of the different parts show that the deposits have a composition of a relatively good clinker cement.

Experimental works: I did not do any semi-industrial experiments with these shales but attended industrial distillation in large kilns. The process goes quite normally in such plants. The melting of ash does not take place at all, because the temperatures are too low; nor are the phenomena of the melting of the organic matter of essential significance because the average percentage was about 15% of the tar content.

In the cement factory Majdan at Solin (near Split) experiments were made in the summer of 1950 in order to get the clinker from the shale and then to produce cement. The final result was highly satisfactory. Normal construction cement of the type of 400 kg cm^2 was obtained by adding 12 per cent of clay which occurs in sufficient quantity in the vicinity of the shale bed.

The oil tar recovered has the melting point about 30°C; separates slowly from the water, and also processes slowly.

The residual gas can be considered as good producer gas.

The mineral residue contains from 15 to 20% of fixed carbon, which is very important in the manufacture of cement.

Exploitation and processing: After the First World War the bituminous shale of Sinj was used in a small scale as locomotive fuel instead of coal. Furthermore, large part of those materials were considered as coal, although they have no coal content at all. On this basis the mine was opened and enlarged. The material happened to be so tough that the mine needed no timbering. This was concluded from the corridors which lasted for several decades without any change. According to that it may be expected that in the future, too, such mining work will be possible, though with more timbering because the work will be carried out at considerable depth.

The mechanisation of transportation from the pit bottom to the surface is possible due to the cheap supply of hydropower.

Though the shale of Sinj is among the best in Europe, I think that exploitation and processing for the recovery of t ars alone would not be economically justifiable, because mining and processing costs would be too high.

On the other hand, the processing itself would be rather simple. The primary distillation could be done with direct combustion of the fixed carbon, and also with the indirect, which would be possibly more favourable in the case of Sinj. In the case of indirect combustion, gas of at least 4,000 to 5,000 kilogram calories per cubic meter could be recovered. The condensation of tars would also be simpler. Consequently, the primary distillation could be solved without any difficulty and normal systems can be used.

As a matter of fact, the processing of tars depends upon the possibility of manufacturing of cement and utilisation of the residual gas.

In connection with this it must be stressed that all necessary raw materials are available at Sinj and in its vicinity: clay used in the processing of oil shales, lignite used in the burning of the mass prepared with clay. There are several lignite deposits in the Sinjako Polje; deposits are accessible to open cast mining methods. By combining of bituminous shales, clay and lignite, clinker cement, tar and gas can be produced without any waste immediately after the primary distillation or even during the distillation. If such a happy combination is taken into consideration, one can see that the Hudo bed of oil shales is of first importance.

Manufacture of cement: Accordingly, it is obvious that the production of cement is of first consideration, the recovery of tars being of secondary significance. The reason is that cheap raw material can be supplied for the manufacture of cement, i.e. the mineral residue after the primary distillation which already contains the fuel necessary for baking the cement clinkers.

The location of the bed is also favourable. It lies in a region which is connected with the western part of Bosnia where the supply of cement is rather difficult. If production of cement started at Sinj, large quantities of cement from the coastal factories could be released and either exported or used in the building of large works where better cement is needed.

Residual gas and its use: As Prof. Margetić reports, a large deposit of high-quality gypsum in large quantities occurs in the same geographical area. The deposit lies on the road between the shale bed and Sinj, near the Glavica site. This gypsum is designed in the first place for exports owing to its quality and its vicinity to the coastal seaports.

Dalmatia is nowadays a large exporter of gypsum, but baked gypsum is not exported in such quantities as it could be. If the residual gas is used for baking of gypsum, the manufacture of it will be cheaper. At the same time the processing of oil shale will be less costly.

Zagreb,
22 January 1953

00-A-24137

Attachment for [redacted]

"Energy Resources of Yugoslavia"